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Review

Teaching, learning and assessment methods for sustainability education on the land–sea interface

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Abstract
The Land–Sea Interface (LSI) is where land and sea meet, not only in physical terms, but also with regards to a large variety of ecological and societal aspects. The United Nations has proclaimed the period 2021–2030 the Ocean Decade, which entails striving for a sustainable use of the ocean and teaching and learning about ocean related issues. Teaching and learning about the LSI are also tightly connected with several Sustainable Development Goals (Global Goals) such as Life Below Water, Zero Hunger and Sustainable Cities and Communities. Teaching and learning about sustainability lacks a uniform pedagogy, and it is probably wise to maintain that apparently adaptive diversity. In this globally relevant methods overview, we present a wide range of relatively new and/or successful and mostly largely learner-centered methods. We also discuss how effective and popular they are, and give examples on how most of these methods are already used in LSI sustainability teaching. There will probably not be any successful "one size fits all" model developing for LSI teaching and learning, and each module, course and programme will have to develop its own recipe for successful teaching and learning, possibly with support from one or several methods discussed in this paper.

Keywords Land–sea interface · Sustainability · Teaching and learning methods · Learner-centered

1 Introduction

Variants of traditional higher education has existed for millennia in many parts of the world [1–4]. Traditional higher education is commonly described as more teacher-centered than learner-centered; i.e., mainly consisting of students listening, observing and repeating what a scholar says and does, with teaching and learning typically set in a lecture hall, classroom, or similar [5–7]. Modern higher education often builds upon such traditions, but also involves various degrees of more learner-centered practices where learners have a higher responsibility in acquiring knowledge and skills in interacting, writing, listening, visualising and idea shaping. Although learner-centered education also has ancient roots [8], the range of newer methods involving more learner-centered activities is wide, and widening [5–7, 9]. In recent decades and in many countries, constructive alignment teaching and learning [10, 11] has become mainstream in higher education [12, 13], although it has also been subject to criticism [14]. Constructive alignment is outcome-based, puts the learner activities and active learner participation in the center, and stresses continuous

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alignment between course objectives and the assessment of student performance. There are many different teaching and learning methods and techniques available, which may be combined with constructive alignment [10, 11, 13].

There is also nowadays an influential paradigm on the global scale in the framework of constructive alignment regarding the use of learning outcomes in higher education [9, 15–17]. Learning outcomes have been defined as "statements of what a learner is expected to know" [9] and may be described as consisting of either or both of two parts: prescribed outcomes and achieved outcomes [18]. Prescribed outcomes are what the student *should* learn during a course or a programme. Achieved outcomes are measurements of what the student *has* learned during a course or a programme [18]. There have been ambitions to shape learning outcomes to become more similar across scientific disciplines, universities and countries, but a large diversity has hitherto remained, providing room for flexibility. There is a vivid academic discussion about the optimal function and shaping of learning outcomes [18, 19]. Outcome should be distinguished from output, which is what the learner produces, and impact, which is the effect or influence on the learner [20].

Another modern feature in higher education is co-creation, which means treating learners like participatory partners in the learning environment, allowing them to contribute to what is learned. Co-creation empowers learners and should be inclusive in order to encourage both highly motivated and less motivated students to become actively engaged [21–23].

The Land–Sea Interface (LSI; sometimes referred to as the coastal transition zone) is where and when land and sea meet; apparently physically, but also in hydrological, ecological, social, economic, cultural, legal, administrative, planning and governance contexts and terms [24, 25]. Studying and addressing problems and challenges at the LSI is a global concern for many reasons, including sustainability, since many of the global Sustainable Development Goals encompass or depend upon the LSI [26]. For instance, the LSI can be sites where rivers discharge anthropogenic pollutants and substances of natural origin, resulting in harmful algal blooms and hypoxia [27]. Coastal ecosystems are home to native and often unique flora and fauna, such as marine mammals, fish, shellfish, seagrass and algae [28, 29]. While being subjected to and affected by numerous natural forces and anthropogenic pressures, these ecosystems also provide a multitude of benefits to humans, so-called ecosystem services [29, 30], as well as general well-being [31]. A substantial proportion (40% according to [32]) of the global human population lives 100 km or less from the sea. People use the LSI for housing, recreation, and for providing for themselves. Coastal and marine tourism is gaining in economic importance [33]. Ports are used for recreational boats, ferries, and marine transportation, the latter being a major and environmentally low-impact way to move goods [34]. Marine spatial planning involves addressing governance and management issues including conflicts of interest in coastal and offshore marine waters [35]. Ecosystem-based management in the coastal zone aims at bringing together all relevant scientific disciplines and stakeholders to solve complex issues in the LSI in a sustainable way [36]. Thus, the LSI has many economic, ecological and social sustainability aspects and involves a large number and a wide range of scientific disciplines.

Sustainability is in itself gradually gaining importance in higher education [37]. The United Nations proclaimed the period 2005–2014 the decade of education for sustainability [38]. It subsequently proclaimed 2021–2030 a decade of ocean science, including aspirations to teach and learn about the ocean (see https://www.oceandecade.org/). Due to the substantial scientific and societal interest for the LSI in particular, in combination with sustainability, sustainability in the LSI has become subject to modules, courses and programmes in higher education in many different parts of the world.

There is a research field of its own called Education for Sustainability or Education for Sustainable Development, aiming to implement sustainability in a wide range of subjects, wherever appropriate [39]. This requires commitment from both faculties and teachers [40]. In Education for Sustainability, a distinction is made between education *on* the environment (focusing on knowledge), education *in* the environment (focusing on emotions) and education *for* the environment (focusing on action) [41]. Each of these three categories needs specifically designed pedagogy, teaching and learning methods, and learning outcomes.

A small selection of recently or currently offered LSI and sustainability related courses and programmes in higher education is provided in Table 1.

The pedagogy used in sustainability education is not uniform but varies to a substantial degree [19]. In line with allowing for and promoting this adaptive variation, the present study explores the actual and potential use of different teaching and learning methods in programmes and courses relating to sustainability in the LSI. The idea is to elaborate a globally relevant overview of recent literature on successful, popular and/or novel methods with practical examples for improved teaching about sustainability in the LSI as they are being applied in different parts of the world. We will also discuss which novel methods are more or less suitable for teaching sustainability in the LSI, which will hopefully be useful for teachers and learners worldwide.

Table 1 A selected sample of higher education courses and programmes currently (2022) or recently taught, with connections to sustainability in the Land–Sea Interface

Course or programme name	Country
Analysing the interdependencies of land and sea [42]	Romania
Maritime operations and management [43]	United Kingdom
Climate change – effects on the landscape and potential solutions [44]	Sweden
Coastal hazards management [45]	India
Biological oceanography and conservation [46]	Pakistan
Regional ocean governance [47]	Thailand
Human and ecological systems [48]	Japan
Ocean macroturbulence and its role in Earth's climate [49]	China
Marine GIS applications for coastal zone management [50]	Malaysia
Coastal and marine science [51]	Australia
Maritime archaeology and underwater cultural heritage [52]	Egypt
Sea level rise and coastal cities: science, policy and practice [53]	United States
Society, environment and sustainability [54]	Canada
Experimental work in marine ecology [55]	Chile

2 Methodology

Literature searches were made in Google Scholar and Web of Science regarding popular and/or novel methods for teaching, learning and assessment. Such searches, in addition to regular browser searches for grey literature and web pages, were also made to determine the extent to which these methods are currently used for sustainability education regarding the LSI. Focus was on the methods rather than on the education programmes. We aimed at identifying examples in different parts of the world to make the overview more relevant in a global context.

3 Relevant teaching, learning and assessment methods for sustainability education on the land–sea interface

This section presents popular and/or novel teaching and learning methods, which may be relevant for the LSI, followed by some occasionally used modern assessment methods. These assessment methods in higher education were included in the section since assessment is an essential part of the learning process [56, 57].

3.1 Traditional classroom learning

Traditional classroom learning may be the most common form of learning in higher education. It is the "gold standard" against which other types of learning is usually compared [58–61]. It also tends to obtain comparatively high ratings by university students [5, 58]. The teacher and learners are typically located in a lecture hall or a classroom, where the teacher lectures, and is often supported by some kind of visual aid [6, 61]. It may be a challenge to adapt classroom learning to constructive alignment, since the latter requires active learner participation. For instance, special individual or group tasks building on examples from the real world could improve learner engagement and activity in classroom learning [12]. Another example is to have learners present and defend work that they have done, and if the peer and teacher criticism is constructive, that could benefit active learning [62]. In an LSI setting, traditional classroom learning is applied to acquiring basic knowledge about foodwebs, coastal biodiversity, port design, maritime legislation, coastal cultural features, coastal currents, sediment-water interactions, marine governance, fisheries science, protection against sea-level rise, coastal ecosystem services, and the influence of catchments on coastal water quality. In Taiwan, traditional classroom learning has been used with regards to coastal revitalisation [63]. New York University, United States, has used such methods for learning about coastal urbanisation and environmental change [64].

3.2 E-learning and blended learning

E-learning over small or large distances is by no means a new method. However, the recent covid-19 pandemic brought about new, albeit involuntary, opportunities for and experience from e-learning, since physical meetings became restricted in many parts of the world [65–67]. Thangajesu Satsish et al. [6] and Maatuk et al. [67] found that this forced online experiment created complementary methods to traditional classroom learning, and that a combination of the two could improve effectiveness, efficiency and interaction in learning, thereby encouraging active learner participation as promoted by the constructive alignment concept. Online learning necessitates more flexibility, support structures and instructional design and could require a greater extent and requirements regarding the organisation of learning activities [6, 61]. Unstable internet connections can be an obstacle in many countries, particularly at the low end of the income scale [65, 67]. According to some studies, e-learning tends to be less popular among university students than traditional classroom learning [5, 68], although opposing results have also been found [69]. E-learning is easily combined with online student interaction and enables students to join courses at sites far from where they reside, and such courses may attract large number of students. For instance, the LSI related university course "Sustainability perspectives on contemporary fisheries: Where have all the fishes gone?" [70] in Sweden (Swedish University of Agricultural Sciences) has e-learning students from all over Europe and other parts of the world who opt not to study in Sweden. The University of Mauritius has used an online platform for teaching coastal zone management, allowing students to participate from remote areas [71]. Many universities worldwide, such as Harvard University in the United States, École Polytechnique in France, and Hong Kong University of Science and Technology in China, offer fee-free online courses on a wide range of subjects including those related to the LSI.

The term blended learning has been defined as "the mixture of e-learning and classroom learning", and uses the benefits of both methods [72]. A meta-analysis by Vo et al. [73] showed positive effects from blended learning on student performance, particularly in science, technology, engineering, and mathematics (STEM) fields. E-learning and blended learning may be a particular challenge, but still possible, in low-income countries [74]. Examples relating to the LSI include the State University of Malang in Indonesia, which has applied blended learning in the studies of beach sports [75]. The University of Aberdeen, United Kingdom, developed computer models for blended learning with the intention to improve three-dimensional understanding of coastal geological processes [76].

3.3 Flipped classroom

Flipped (or inverted) classroom techniques have developed and increased in use over the past decade, particularly in the United States [77, 78]. The idea with the flipped classroom is, first, for the learner to study lectures, videos, blog posts, podcasts and similar material using computers or other technical devices at home before class. Such activities are, second, combined with meeting peers and lecturers at the university for learner-centered group discussions, problem solving and other activities relating to what has been done at home [77, 78]. This method is highly compatible with constructive alignment since participatory learner roles are encouraged. There has also been criticism against flipped classroom techniques for, e.g., being too technology dependent, for not clearly improving study results, and for having different effects on different learner groups [79]. Evidence on the overall effect of flipped classroom on learning performance appears to be quite ambiguous and case dependent [80]. Nevertheless, several student satisfaction studies have shown that university students tend to prefer flipped classroom to traditional teaching in higher education [81–84]. Li et al. [85] described the use of computer based methods at home in a landscape architecture course, where problems that arose with landscape design were discussed in class. There is also plenty of free online material available to additionally advise and facilitate flipped classroom teaching and learning about the LSI. For instance, the course module "Ocean Physics & Climate Change" in the United Kingdom (UCL, London) lets learners summarise the previous lecture using any chosen kind of technical support, as an initiating attempt to apply flipped classroom techniques [86].

3.4 Problem-based learning

Problem-based learning (PBL) has been popular in higher education for several decades. Learning is performed in a group, which is presented with an open-ended problem. Problem-based learning is thus learner centered (as suggested in the constructive alignment paradigm) and develops group cooperation skills, communication skills, project management skills and real-world experiences [87]. Effects on critical thinking skills have been disputed, but a recent meta-analysis by Liu and Pásztor [88] found strong positive effects. Effects of PBL on learning effectiveness have been investigated with mixed outcomes, although effects on long-term learning tend to be positive compared to conventional classroom learning [89]. There is, however, still a great need to develop measurement instruments for properly evaluating PBL compared to other teaching methods [90]. In Taiwan, PBL has been used in higher education to study the revitalisation of a coastal area [63]. In the United States, PBL has been applied in higher education to study land subsidence and rising sea levels [91].

3.5 Crossover learning

Crossover learning is an umbrella term for methods which bring together informal and formal learning. This could mean supervised visits and active participation at a museum, a conference hall, a stakeholder workshop, a poster session or virtually anything outside of the university walls [94–97]. Azmi et al. [92] found high (mostly > 4 on a scale from 1 to 5) student ratings for a teacher facilitated but student-led crossover learning event. Couper et al. [97] organised an event intended for crossover learning in Australia about turtle ecology and plastic pollution in the LSI. Active learner participation makes this method suitable in the framework of constructive alignment.

3.6 Field trips and excursions

Field trips and excursions are costly but popular parts of courses that stimulate interest in the topic and provide first-hand experience, personal development and opportunities for social interaction. The learner gets to travel to a place where the subject taught is performed in practice, and the field trip or excursion is often combined with practical exercises [98]. Field trips and excursions enable unique kinds of learning that is not possible to replicate in class and are performed in a wide variety of fields, including natural and social sciences [99]. Activities often require substantial learner engagement, and thus conform well to constructive alignment. The University of South Florida, USA, arranges physical field trips in higher education focusing on coastal ecology, coastal geology, watersheds and coastal conservation [100]. An increasingly popular variety of field trips, which may be less costly than physical field trips, but offering less social interaction, is virtual field trips, where learners get to experience topics via computer. Virtual field trips with a partial coastal focus have been developed in earth and environmental sciences at Ankara University, Turkey [101]. A collaboration between several European universities offers virtual field trips on coastal geomorphology, sea-level changes, coastal adaptation to climate change, and socio-economic development focusing on a coastal bay [102].

3.7 Game-based learning

Yet another learning field, which has gained popularity in recent decades, is game-based learning (GBL). A game is typically designed by experts and programmers, and played by the learner, who acquires knowledge and skills while playing actively, and have access to support from an instructor. According to Subhash et al. [103], Pellas and Mystakidis [104] and Zou et al. [105], GBL improves learner motivation and performance in higher education. However, gamification requires reliable and costly computer hardware and software programming, which must often be maintained and updated regularly [103]. GBL in higher education has been described in numerous studies, some of which have a certain relevance to sustainability and the LSI. For instance, Weines [106] evaluated GBL with focus on marine resource management. Keogh et al. [107] found that GBL regarding sports biomechanics increased learner engagement. Improved learning among university students was found by Türkistanli and Kuleyin [108] regarding a game-based decision support system in maritime transportation engineering. GBL can also improve learning of sustainability issues and conflict management according to Makri [109].

3.8 Spacing and self-testing

Spacing (sometimes referred to as “spaced learning”) is a method developed by neuroscience, cognitive research and adjacent disciplines and aims at optimal training of the long-term memory. Highly intensive and compressed learning segments are repeated several times each and are interrupted by non-stimulus breaks [110]. Self-testing is performed by the learners themselves and involves testing their understanding of a topic by assessing the accuracy of memorised information [111]. These two methods can be very effective compared to other forms of learning, and this relative effectiveness is poorly known by both teachers and learners [110–112]. Searches in the databases Google Scholar and Web of Science indicated that self-testing is used in a wide range of scientific fields, and much more so than spacing. Both methods should nevertheless have high potential in LSI and sustainability teaching and learning.

3.9 Continuous assessment

Continuous assessment in higher education has been defined as "the use of tests over a learning unit, and the accumulation of results in a final grade" [113]. Assessment may, for instance, be performed on a weekly basis [114]. Frequent assessment occasions could require more effort from the teacher, and may be difficult to finance in courses with low student numbers. Nevertheless, continuous assessment has overall been found to increase student engagement and improve learning outcomes [114]. Passing rates increased sharply among coastal engineering students at the University of Cadíz, Spain, after continuous assessment was introduced [115]. Jonas [33] developed a curriculum framework for a coastal and marine tourism education programme at Nelson Mandela University in South Africa and found that continuous assessment of students was particularly popular among stakeholders in the tourism sector.

3.10 Formative assessment

According to Boston [116], "[a]ssessments become formative when the information is used to adapt teaching and learning to meet student needs". Formative assessment can be continuous, but can also be very occasional [117]. Three practical examples are quizzing, peer feedback and teacher feedback [117]. However, the impact of formative assessment on student performance and satisfaction in higher education has only been subject to limited investigation, and the scant evidence available tends to be mixed [118]. There seems to be limited use of formative assessment in LSI teaching and learning in higher education.

4 Discussion and conclusions

According to the overview presented in this paper, there is intensive development of new teaching methods ongoing with relevance for sustainability in the LSI. New methods tend to have a strong learner-centered focus, which is in line with the influential paradigm of constructive alignment. The pedagogy varies between courses and programmes and there is probably no "one size fits all" teaching and learning model for all LSI related courses. It is probably wise to maintain a high diversity in methods and select different methods for different purposes. It is likely that traditional classroom learning [5, 58] will continue to play a major role for teaching and learning sustainability in the LSI, preferably with a substantial role of active learner involvement. Experiences from the recent pandemic has highlighted the advantages and disadvantages with e-learning and blended learning [65–67] and that experience should be taken into account when developing or modifying LSI courses. E-learning and blended learning may attract additional students from far away in relation to where the course is taught. Flipped classroom techniques [77, 78] and problem-based learning [87, 88] may be suitable for some LSI related modules, courses and programmes, but less so for others.

Field trips and excursions [98, 99] are popular elements of various LSI courses and may improve learner satisfaction, increase student enrollment, and offer unique opportunities for learning, which may not always be available in classrooms or lecture halls. Game-based learning [103–105] may elevate motivation and bring variation to teaching and learning in an LSI setting, although it requires efforts to create and update games in order for them to be relevant.

Crossover learning [92–96] can probably be arranged as a part of a course, in order to attain variation, to increase student engagement and relate other activities to the real world in which the students will eventually work. Spacing and self-testing [110–112] have great potential for substantially improving learning efficiency, and we encourage teachers to explore these methods and possibly incorporate them in their curricula. Continuous assessment requires extra effort and resources, but may nevertheless improve passing rates of students [115]. The efficiency of formative assessment has yet to be investigated properly [118], but that may be a method worth exploring and evaluating in teaching and learning related to sustainability in the LSI. There are many additional novel teaching and learning methods available [59, 94], which were not explored in this study for reasons of brevity.

The current teaching and learning methods on sustainability in the LSI should also consider exposing the students to the policy interface between science and management; and stakeholder interactions. In this respect, the Stanford Center for Ocean Solutions and the Stanford Law School, at Stanford University, developed a course on: 'The Outlaw Ocean Policy Practicum'. The course outcome resulted in two comprehensive student reports [119, 120], two extremely valuable and timely contributions to ocean and global sustainability, given the multitude of national and global ambitions and agreements to promote and strive for these wider goals. Two other aspects that need to be considered in relation to sustainability and equity are: (a) the inclusion of local and indigenous knowledge systems, to integrate cultural, social interactions and different worlds views, as part of a complex knowledge network that is important to inform decision-making processes [121], and the UNESCO initiative on 'Local and Indigenous Knowledge System (LINKS)': https://en.unesco.org/links; and (b) the inclusion of Ocean Literacy as a framework for enhancing knowledge sharing across all sectors of society and improving our understanding of the role that the oceans have in our well-being (UNESCO Ocean Literacy: https://ioc.unesco.org/topics/ocean-literacy and [122]).

To conclude, this paper has provided and discussed an overview of selected teaching and learning methods, which may be globally relevant in the context of sustainability in the LSI. Some of the newer methods have been explored more thoroughly in relation to education in other scientific disciplines, and we think it is time to consider them in teaching and learning about sustainability in the LSI as well. While there is a substantial variety in pedagogy and methods in sustainability education regarding the LSI, we hope that this paper can serve as a fact-base and inspiration to course leaders and programme developers in this area.

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Declarations

Competing interests The authors declare no competing interests.

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