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Review

Developing Design Principles for Sustainability-Oriented Blended Learning in Higher Education

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Abstract: Climate change forces higher educational institutions (HEI) to reconsider their traditional ways of teaching and organising education. This implies that they should reduce their impact on the environment and provide sustainability-oriented education. Blended learning (fusion of on-campus and online learning) may provide an appealing solution to achieve both objectives. It may reduce HEI's climate impact by reducing student travel to and from campus and support the development of students' sustainability competencies. In this paper, pedagogical design principles and recommendations are developed to design such a sustainability-oriented blended learning configuration. A realist review methodology is used to distil and develop pedagogical principles for blended learning. These principles were mirrored against pedagogical approaches that have been identified as suitable for developing sustainability competencies. This mirroring revealed some overlap but also some notable differences. Common principles include self-regulation, community building, discussion, knowledge management, and collaboration, but some principles identified in sustainability-oriented education are noticeably absent, including self-awareness, orientation towards sustainable change, and interdisciplinary collaboration. The insights guide designing sustainability-oriented blended learning and vice versa can also provide ideas for people working in off-line place-based contexts on sustainability-oriented education, to consider blended options.

Keywords: blended learning; sustainability competencies; design principles; travel behaviour; sustainability-oriented learning; pedagogical approach

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1. Introduction

Seemingly unrelated developments in climate urgency and information and communication technology (ICT) challenge higher education institutions (HEIs) to reconsider their traditional ways of teaching. To contribute to addressing climate change, HEIs should take measures to lower the climate impact of their organisation [1] as well as provide sustainability-oriented education [2], that can help develop and unfold the competencies students need in a climate-changed world [3,4]. Technical developments in ICT provide higher education (HE) with the possibility to create a virtual educational space adjacent to the physical space of the campus. This virtual space became the only space students could use for their learning during the COVID-19 pandemic when most HEIs made a rapid transition to so-called "emergency remote teaching" [5]. This forced response seems to have accelerated a development in HE to consider a mix of on-campus and online learning (so-called blended learning).

Blended learning (BL) can be deployed as a means to lower the climate impact of an HEI by reducing student commuting to and from campus [6]. Across the globe, students' travel to and from campus is a large contributor to carbon emissions. Visiting a virtual space is place-independent and can reduce travel movements and associated carbon

footprints [6,7]. According to the study by Caird et al. [7], distance-based HE teaching models (distance, online, ICT-enhanced) achieve carbon reductions of 83 percent in comparison with on-campus models (in-class, ICT-enhanced). This is for the most part due to commute-related student travel, especially to universities and former polytechnics that provide no or very little on-campus housing. Indeed, the use of ICT also has a carbon footprint but one that is minor in comparison [7]. Considering these findings, an educational design limiting on-campus learning to one or two days per week supplemented with online course delivery, thus reducing commute-related student travel, seems to be one obvious possibility for HE to meet its sustainability objectives. Combining on-campus learning, where student–student and lecturer–student interaction is crucial, with online learning might create an optimal learning environment both from an educational and a sustainability perspective. A focus on travel reduction can be seen as an institution's effort to "walk the talk" and can, when combined with a broader vision of sustainability and an institution´s aspirations to help realise the Sustainable Development Goals (SDGs) [8], also provide a way into strengthening students' sustainability competencies [3,4].

In combining these two vantage points, we come to the following overarching research question: how to design a blended learning configuration that can both reduce students' travel-related carbon emissions and enhance their competencies to meaningfully engage in sustainability challenges?

To be able to answer this question, we first need to discuss what is meant by the educational quality of BL. The sustainability competencies will be addressed in the next section. This study only considers the design quality of a blended course or curriculum, not the quality of management processes. It focuses on how a blended design can promote student learning. BL, like all education, has a normative aspect in that it willingly or unwillingly promotes certain values and behaviours. If reducing the environmental impact of HE on climate change by mitigating student commute is a normative aim, then one of the indicators of a blended design should be the extent to which online learning is used to substitute on-campus learning to realise (and disseminate) this normative aim. In line with Allen and Seaman [9], we call a course or curriculum blended when a large portion (typically anywhere between 30–80 per cent) is delivered online. However, to enhance educational quality, a blended educational design requires more than just adding ICT enhancements to on-campus courses as it constitutes a fundamental redesign of the educational approach [10,11]. This is because BL changes or extends the mode of interaction with fellow students, lecturers, and content [10]. BL can improve a student's engagement and learning outcomes [12,13] but needs to consider factors such as, "educator presence in online settings, interactions between students, teachers and content, and deliberate connections between online and offline activities and between campus-related and practice-related activities" [14] (p. 53). BL can be engaging for students and has the full attention of HE after COVID-19 [15], but it is unclear how it may support developing students' sustainability competencies. This study wants to make a contribution to fill that gap.

In summary, blended education comprises a responsible fusion of online and on-campus learning. The term "responsible" is used because the fusion is characterised by using a pedagogical approach to integrate online and on-campus learning that is mindful of the normative aspect of education as well [16]. To gain insight into how to develop a responsible BL model, we will answer the following (sub) research questions:

RQ1. What design principles characterise high-quality blended learning in higher education?
RQ2. To what extent does high-quality blended learning support students' development of sustainability competencies?

In the next section, some background is provided about education that aims to foster students´ sustainability competencies in relation to BL. In the methodology section, the review approach will be introduced, followed by the results presented according to the research questions. In the last section, we end with a discussion of the results including suggestions for further research.

2. Blended Education for Developing Sustainability Competencies

To determine educational strategies that can foster competencies that are essential for students to address the complex sustainability challenges in a climate-changed world, we first need to articulate what these competencies are. A competency is an in-situ combination of knowledge, skills, and attitude needed to accomplish the desired educational outcome [4,17]. Brundiers et al. [3] have collated and synthesised the sustainability competencies that have emerged in higher education contexts over the last decade or so. These competencies include systems thinking, strategic thinking, value thinking, futures thinking, interpersonal, intrapersonal, and implementation competency. These competencies are interconnected; for instance, developing strategies for transformative change (i.e., strategic thinking) requires analysing the underlying problem while considering the nested systems of which it is part (i.e., systems thinking), applying and assessing sustainability values while considering ethics (i.e., value thinking), and considering future consequences (i.e., scenario thinking), using this knowledge and understanding to realise a solution to a sustainability problem or make an attempt to improve the situation (i.e., implementation) [3,4]. Every step of the process should be of an inter- or transdisciplinary and collaborative nature [3,4]. Next to these key competencies for sustainability, there are some general basic competencies which serve "as the foundation of academic sustainability education" [4] (p. 212) such as critical thinking, research, data management, and self-regulation skills. The educational challenge is to identify which pedagogical approaches are appropriate to develop these (key) competencies in students and, in our case, whether a BL design can be supportive or counterproductive.

Two features emerge when considering a BL environment for developing students' sustainability competencies, namely, place-independency and just-in-time education. Place-independency, as stated before, may affect the travel behaviour of students by decreasing their travel movements, but it can also widen the horizon for students. In BL, a student can use the virtual space to collaborate and interact with students from different disciplinary, national, and cultural backgrounds together at a place and time of their choice without the environmental and financial costs of travel [18]. This provides opportunities for developing interpersonal or transboundary competency, as De Kraker [18] calls it, by incorporating different perspectives while having group discussions and organised feedback [18]. Moreover, this flexibility of time and place broadens access to learning opportunities [19].

Digital technology creates networks that connect not only people but also systems, establishing "a rapidly evolving information ecology" [20] (p. 3). Today's certainties in the sciences technology, politics, economy, society, and culture are constantly outdated by new insights [21], making it vital to know how and where to find reliable knowledge and, in addition, how this information can be interpreted in the context of social, economic, and environmental issues. A complicating factor is also that the amount of knowledge, available through the World Wide Web and, more recently, AI-powered chatbots such as ChatGPT [22] has been increasing exponentially. For these reasons, learning cannot be a linear process of acquiring knowledge and skills anymore but should become a continuous process, lasting for a lifetime [3]. Therefore, HE should prepare students for this just-in-time education [23] and BL can probably provide an appropriate learning environment [24].

3. Methods

3.1. What Design Principles Characterise High-Quality BL in Higher Education? (RQ1)

Introducing BL meets the key characteristics of a complex social intervention as formulated by Pawson et al. [25]. A BL intervention is embedded in the social system of the educational organisation, influenced by the motivations and intentions of the stakeholders (lecturers, management), and is susceptible to change due to different and changing circumstances. Subsequently, there is no prescription possible on how to design and implement BL, and negotiation and feedback are necessary at each stage [26].

A realist review approach seems to recognise and address this complexity by considering the context of each experience. The aim of a realist review is explanatory: "what

works for whom, in what circumstances, in what respect, and how?" [25] (p. 5). However, considering BL, the contextual factors influencing a blended design are never the same and possible design options are almost unlimited [27], each of which constitutes an intervention to be studied in its own right. The ambition to meet the aim of a realist review while studying BL must be scaled back because such a complex system only allows "an understanding of partial and situated systems rather than whole and general ones" [28] (p. 8). Therefore, a pragmatic approach was adopted to still make use of the explanatory strength of the realist review. This pragmatic approach is consistent with the iterative and flexible nature of realist review, rejecting standardisation or prescription [25,29]. It entails:

- Empirical evidence is included in this study when it supports (or contradicts) at least one of the initial design principles extracted from theory.
- When considering how the context affects the intervention, the context is reduced to three typical blends between online and in-class education (Section 3.1.3, Synthesise findings). Positive as well as negative effects are taken into account.
- Stakeholders are not consulted, although this is believed to be a key feature of a realist review [29]. Instead, the choice is made to discuss and refine the usability of the BL design principles for sustainability-oriented education through an additional literature review.

In this study, initial design principles are developed based on BL theories of authors leading in the field of BL science, and the applicability of each of these principles is assessed in a variety of learning contexts by studying several empirical studies.

The systematic review approach consists of four stages (based on Pawson et al. [25]):

1. Develop initial theory. The initial design principles are extracted from theories about BL.
2. Search for literature. Evidence is gathered from empirical studies to test and refine these principles.
3. Extract and synthesise findings. By applying CIMO logic, that is, "in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)" [30] (p. 395), the findings are analysed and compared with the initial design principles.
4. Distil recommendations for practice. Recommendations are extracted from the findings.

Although stages are defined, the process within each stage and between stages is iterative. New evidence may change the direction [25].

3.1.1. Stage 1. Develop Initial Theory

The initial principles are extracted from three works of authors about blended/online learning, so-called programme theories. These works were chosen because they contain well-established theories and differ in perspective on how to design BL.

Laurillard [31] specifies in the Conversational Framework the (iterative) interactions between students and lecturers and also fellow students linking both theory and practice. These interactions change while studying online or on campus [31]. A strength of Laurillard's is that it captures the essence of teaching as an iterative dialogue between teachers and learners while functioning on the following levels: a discursive, theoretical, conceptual level; and an active, practical, experiential level, i.e., the levels bridged between teachers and pupils while engaging in the process of critical thinking and reflection.

Although the Conversational Framework includes interaction cycles during student collaboration, the social aspects of working together are not part of the framework. Garrison and Vaughan [32] fill this gap with their Community of Inquiry Framework, specifying the process of integrating social, cognitive, and teaching elements of a community of learners, collaborating in a blended setting.

Ellis and Goodyear [33] developed a more, what we might call, Integrative Relational Framework by treating the learning environment as an ecology of learning [34] in which online and on-campus learning is integrated and ecologically balanced, evaluating a student's approach to learning in this context [33]. This work aligns well with sustainability-oriented learning concepts [2].

3.1.2. Stage 2. Search for Literature

A systematic, step-by-step approach was conducted to ensure transparency and rigour in searching the databases. We have chosen two databases that allow for searching with logical operators and wildcards, that is, the ERIC library and Web of Science, both well-suited for education-related research.

Given that technological innovations are going fast and have a deep impact on the quality of online learning, the search was restricted to articles with a publication date after 2010. More pragmatically, this criterion also helped to keep the number of articles manageable. The search was conducted in May 2020. In all the searches, the terms "blend* OR hybrid" (in title) and "higher education" were included. In the second iteration, we also added "OR flipped" in the in-title search term, as work on flipped classrooms also connects with this topic. Keywords were extracted from the initial design principles to be used as additional search terms and wildcards were added to capture similar (but not completely the same) terms used in the text (Table 1).

Table 1. Search expressions with keywords extracted from initial design principles (in Table 5).

Design Principle	Search Expression
Learning process	"self-direct*" OR "self-regulat*" OR "self-navigat*"
Learning climate	affective OR "social presence" OR "personal relationship#"
Interaction and discussion	discussion OR "social interaction" OR "critical discourse"
Acquisition and inquiry	acquisition OR "content knowledge" OR inquiry OR "cognitive presence"
Practice	"practi*" OR "task#" OR "laborator*"
Collaboration	"collaborat*" OR "community of inquiry" OR "community of practice"

The database search started adding the search terms of all principles. As expected, this expression yielded no results in either of the databases. Every search expression was added separately and in combination with others, which eventually resulted in 22 searches. After deleting duplicates, the result list contained 230 articles.

These 230 articles went through a filtering process (Table 2). During the filtering process "Reading the full paper", the paper was also assessed by using guiding questions based on CIMO logic (Table 3). In the end, 38 studies remained for analysis.

Table 2. Summary of selection criteria. Based on [35].

Filter	Method	Reasons for Exclusion	Papers Remaining
0	Bibliographic searches		230
1	Reading of abstract	Studies not situated in higher education Studies not about didactical issues Studies about specific tools, devices, or learning activity Not regular higher education, i.e., adult education Studies not reviewed About mobile technology BL in a special context (minority groups, virtual world) Solely a comparison of online and BL Study of adoption of BL in the institution Same as filter 1	85
2	Reading of full paper	Not substantially substituting face-to-face with online learning Research situation mainly online, not blended Described intervention not relevant to the design principles Review Only describing the didactical model, no mechanisms are mentioned BL intervention is not clearly described Validity of the results Research is focussed on teacher experiences Only outcomes are specified, not the mechanisms leading to these outcomes Intervention is a technology decreasing in popularity among students (Twitter) The blend is specific for a special profession	27
3	Backward snowballing	Extracting empirical studies from the references list of a (recent) review [14] about BL and repeating filters 2 and 3.	38

Table 3. Research questions based on CIMO logic. Based on [36].

Component	Research Questions
C—Context	What is the learning context (institution, nr of students, study phase, subject)? What research method is applied?
I—Interventions	What actions, executed online or face-to-face, are formulated by the designer(s) for implementing a BL intervention that applies to one or more of the initial design principles?
M—Mechanisms	What are the underlying generative mechanisms triggered by the intervention in a certain context, indicating why the intervention produces a certain outcome?
O—Outcome	What are the results of the interventions in their various aspects?

3.1.3. Stage 3. Extract and Synthesise Findings

Data extraction forms based on CIMO logic were developed and populated with the extracted data of each paper. The next step in this stage was comparing and contrasting the findings from the different studies and finally, the results were compared with the initial design principles of stage 1.

Extracting Data

The theoretical knowledge base about experiences with BL is structured by using CIMO logic [30] (Table 3). A step-by-step approach to extracting the empirical findings about the initial design principles is applied:

1. The 38 articles were uploaded in ATLAS.ti (version 8) and coded according to CIMO logic. Every article received codes such as ['C','I','M','O'] [nr of article] [acronym of design principle], for instance, "C_2_SLE". The acronym of the design principle can be retrieved from Table 5.
2. Appropriate data were extracted from each article and ordered according to CIMO logic

Synthesise Findings

In the next step, the findings from the 38 papers were analysed and synthesised with the programme theories. To include contextual data, a context Table A1 (Appendix A) was created in which data has been gathered about some characteristics of the students involved in the study (age and study phase), the course subject, and the didactic method applied. Through the reference, all mechanisms and recommendations can be traced back to their context. The design of the BL configuration was generalised according to three typical blends between online and in-class education, namely; (1) online: knowledge acquisition and in-class: practice (so-called flipped learning), (2) practice and knowledge acquisition more or less equally divided between online and in-class learning, and (3) practice and knowledge acquisition more or less equally divided between online and in-class learning supplemented with collaborative learning. For each of these learning configurations, the associated mechanisms (positive change and areas of concern) were gathered per design principle. Finally, these findings were compared with the programme theories and the initial design principles were, if required, adapted to evolving insights.

3.1.4. Stage 4. Distil Recommendations for Practice

Recommendations to optimise a BL configuration are extracted from the synthesised findings (generative mechanisms (positive change and areas of concern) in the different contexts).

3.2. To What Extent Does High-Quality Blended Learning Support Students' Development of Sustainability Competencies? (RQ2)

The general BL design principles are mirrored against what is needed to develop sustainability competencies and the corresponding pedagogical approaches. We based our analysis on well-cited references in literature about sustainability-oriented education or making the connection of sustainability with online learning in higher education (Table 4).

Table 4. Consulted scientific studies about sustainability-oriented learning.

Subject	Scientific Literature	
Sustainability competencies	Wiek et al. [4]	A highly-cited review article providing a framework of key sustainability competencies to be used in HE
	Brundiers et al. [3]	A further elaboration on the key competencies of Wiek et al. [4]
	Lozano et al. [17]	A framework of 12 sustainability competencies, to be used in HE, is connected to pedagogical approaches to develop these competencies
Pedagogical approach for sustainability	Lozano et.al. [37]	A framework of 12 sustainability competencies connected to 12 pedagogical approaches, classified into three categories.
	Tejedor et al. [38]	Focus on didactic strategies relevant to the development of sustainability competencies.
	Wals [2]	Key characteristics of a sustainability-oriented ecology of learning supplemented with an underlying emancipatory pedagogy.
Empirical studies: online learning and sustainability	Sibbel [39]	Exploration of the potential of a BL course conducted with a constructivist approach and principles of knowledge management, to promote education for sustainability
	Archambault and Warren [24]	Study of a blended course, Sustainability Science for Teachers, integrating the use of technology and digital storytelling to engage students in sustainability topics.
	Hesen et al. [40]	Fostering subjectivation and creating a sense of community in an online course on Environmental Education for Sustainable Living
	De Kraker et al. [18]	Application of an effective learning environment to foster transboundary competency through virtual mobility

4. Results

4.1. Design Principles of BL (RQ1)

The findings are presented according to stages 1 and 3 of the realist review approach. Stage 2, the literature search, resulted in 38 studies (Appendix A). These studies are analysed and interpreted in stage 3 using the initial design principles. The resulting recommendations are derived from stage 3.

4.1.1. Stage 1. Developing Initial Design Principles

The selected authors developed well-established theories that give direction to the design of a BL configuration. The initial design principles are extracted from these programme theories, which will be discussed first.

Programme Theories

Diana Laurillard, Teaching as a design science.

Laurillard [41] developed the Conversational Framework based on a synthesis of former pedagogical research about what it takes to learn. This general framework represents learning and teaching in any form, conventional or technology-enhanced. It specifies the iterative transactions between student–teacher and student–fellow students on two contrasting levels: (1) articulating and discussing theory and (2) experimenting and practising on goal-oriented tasks. In Teaching as a Design Science, Laurillard [31] builds upon the

Conversational Framework to design education with digital technology and in particular discusses the design of learning activities for this pedagogical technologically enhanced approach. These activities are learning through acquisition of knowledge, applying theoretical concepts into practice, inquiry making use of resources, peer discussion, and collaboration to construct a shared outcome [31].

Randy Garrison and Norman D. Vaughan, Blended Learning in Higher Education, Framework, Principles and Guidelines.

Garrison and Vaughan [32] describe the educational processes of a community of students in the Community of Inquiry Framework. The core elements of this framework are social presence, teaching presence, and cognitive presence. Social presence is about cultivating a community where students can develop personal relationships. Teaching presence "provides the design, facilitation, and direction for a worthwhile educational experience" (p. 31) and cognitive presence "maps the cyclical inquiry pattern of learning from experience through reflection and conceptualisation to action and on to further experience" (p. 29). This framework is used to introduce seven design principles for BL [32]. These principles provide direction as to how the teaching presence of a lecturer can create and sustain a social and cognitive presence.

Robert Ellis and Peter Goodyear, Experiences of e-learning in Higher Education: the ecology of sustainable innovation.

Ellis and Goodyear [33] consider how students learn within the larger environment in which they study. They address this learning environment as an "ecology of learning" with "good learning" as a common goal for students, teachers, service providers, leaders, and society. An ecological balance should be maintained in a rapidly changing world; for example, consider technological innovations. According to Ellis and Goodyear [33], students are looking for a balanced use of technology, not reducing access to their teachers. In their Integrative Relational Framework, Ellis and Goodyear [33] argue that an effective replacement of a portion of face-to-face experience by e-learning is "one that seeks harmony of the parts, is integrated and ecologically balanced to focus students on learning outcomes and the development of understanding" (p. 75). They think that two learning activities are particularly suitable for e-learning, namely learning through discussion and learning through inquiry [33].

Initial Design Principles

Following Laurillard [31], the first design principles developed (Table 5: ID, AI, PR, CO) are based on the learning activities in which the students participate, that is, learning through discussion, acquisition, practice, and collaboration. Next, a design principle about creating a safe and social learning environment (Table 5: SLE) was added to the principles based on the element "social presence" in the Community of Inquiry framework of Garrison and Vaughan [32]. In addition, learning by discussion (Table 5: ID) is supplemented with the term "interaction", indicating an unstructured form of a student's interactions with the lecturer and fellow students. All three authors emphasise the importance of the learning process principle (Table 5: LP). The programme theories provided design principles and the effect they may have when applied adequately in BL (Table 5).

4.1.2. Stage 3. Extract and Synthesise Findings

In the following sections, the identified mechanisms (positive change and areas of concern) will be discussed and compared with the initial design principles (stage 1) for each principle. The initial design principles will be adapted if there is a reason to do so. The reference can be used to trace back the context of the BL intervention in the context Table A1 (Appendix A).

Table 5. Initial design principles for a BL configuration.

Design Principle	Laurillard [31]	Garrison and Vaughan [32]	Ellis and Goodyear [33]
Aiming at self-regulation of learning and practice in a student's learning process (LP)	Coached by the lecturer but learning independently (using the internet), fosters a context in which a student can develop self-efficacy beliefs, important for academic experiences	To shape cognitive and metacognitive processes and learning, students should aim at becoming self-directed, best explored in a face-to-face context and reflected upon in an online context.	Learning is self-regulated and goal-oriented. Opportunities should be created to make personal choices concerning goals, study and assessment methods, place, and time.
Facilitating interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking (ID)	During the interaction cycles of the student with a lecturer and fellow students' concepts, goals, or practice capabilities are modulated and will generate in this way new actions in a continuous iterative process of development and learning. In an asynchronous online discussion, a student has time to reflect, modify, and articulate their contribution.	A strong "teaching presence" is necessary to shape the interaction between students into a reflective and critical discourse. Online learning supports reflection and in-class learning, verbal agility, and spontaneity.	Online learning should use the opportunities of interactivity, adaptivity and "intelligence" in the online resources, and rich human–human communication. Discussing and understanding each other's positions on significant (real-world) issues is an important aspect of academic learning.
Fostering a safe and social learning environment (SLE)	A lecturer should try to create for the student a sense of belonging to a group. It can change a student's attitude towards academic work.	The term "social presence" indicates that students in a community of inquiry should develop an environment in which they feel safe to express themselves and challenge ideas. In-class learning establishes this environment.	Learning activity is socially situated, that is, being a part of a learning community affects students' approach to learning through relationships with other people.
Transforming learning through acquisition and inquiry into an active process based on existing knowledge (AI)	To activate learning through acquisition (teacher communication cycle), the lecturer must 1. create a sense of need to know, 2. use familiar concepts, 3. use multiple representations of a concept, and 4. use the principles of the cognitive load theory.	The term "cognitive presence" indicates learning through inquiry. Online discussions encourage a more integrated and deeper level of thinking. Face-to-face discussions are conducive to creating new ideas and task management.	Every student has their unique approach to constructing knowledge by using 1. past experience and existing knowledge and 2. a surface or deep approach to learning. Learning through inquiry: An active, authentic, and student-centred form of learning
Working on authentic tasks with scaffolded and theory-based practice (PR)	The lecturer provides exercises that are in a student's zone of proximal development and contain formative intrinsic feedback. Students may use these exercises to reflect upon and adapt their conceptual understanding, studying online.		Online learning methods and tools can create opportunities to support the transfer of learning from the classroom to the professional setting by designing online learning tasks and tools which align with the workplace setting.
Collaboration for constructing a shared outcome through participation and negotiation with fellow students (CO)	Students can learn from each other and get motivated by practising with one another. A Computer Supported Collaborative Learning Environment can promote this process of articulating and critiquing points of view.	The learning environment of a community of inquiry integrates social, cognitive, and teaching elements and stimulates critical reflection and discourse.	The participation of students in a community of practice is inseparable from learning.

Aiming at Self-Regulation of Learning and Practice in a Student's Learning Process

In BL, a student needs to have or develop the ability to structure and plan the learning part outside the classroom [42–47]. The student's learning outcome is affected by their level of self-control (dispositional personality characteristic) and self-regulation at the beginning of the blended course [43,48], although self-directedness (metacognition and motivation) has been found as a more significant influencing factor for performance in flipped learning [42,49]. In addition, the self-efficacy beliefs of students are found as a significant predictor of their learning performance [46]. Coaching and motivating students to study regularly seems to be necessary, illustrated by the observations of students, following a flipped learning course, who experience the online learning part as time-demanding and feel pressure to go to class prepared [44,45].

Therefore, several approaches are mentioned in the reviewed studies to coach and motivate students. At the beginning of the course, or even before, it is recommended to offer pre-course orientations and in-course intervention for students new to the online learning environment [48]. During the course, to encourage students to study regularly, direct feedback on their performance is stimulating [47]. This feedback can be provided by online tests and quizzes [50], but also by the lecturer, whose presence should be apparent throughout the course in supporting the students [44,51]. Additionally, online feedback from fellow students can be helpful, but this needs scaffolding because students are reluctant to record criticism online of their peers' work [42,52]. Lastly, a digital learning environment can have learning analytics functionality that automatically generates warnings to students if they spend insufficient time on their tasks [49]. Fellow students can also play a stimulating role when students get the opportunity to implement their tasks in a team project [47,53]. In this way, they can experience other students' processes and work. This increases motivation and positive competition [54]. Considering the participation of an individual student, this is positively affected when there is a choice between online assignments meeting his/her learning style [55]. Additionally, gamification elements can be added to the blended design, although these elements were not in all cases effective [56].

Although self-regulation seems to be difficult for some students [57], they appreciate the opportunity to study anytime and anywhere [58,59].

Adapting learning materials to the different learning styles of students to enhance motivation is hardly mentioned in the programme theories. Ellis and Goodyear [33] state that lecturers should stimulate students to take control of their learning process by helping them to make their own choices. They mention "empowering learners" through loosening administrative (place, time, and study costs) and educational (goal, study, and assessment methods) constraints as an opportunity for online learning [33].

Fostering a Safe and Social Learning Environment

The programme theories emphasise the importance of an environment in which students can develop relationships with other people and feel safe to express themselves. This is confirmed by several reviewed studies [51,57,60,61]. These studies add some best practices and propose strategies how to foster emotional closeness online as well as in class.

In-class activities can foster emotional closeness. If a lecturer provides opportunities for interaction and thus creates a friendly atmosphere, social connections can be made [51,57]. This is especially important at the beginning of the blended course [58]. If there is limited time for interaction during in-class sessions, online blogging activities for students may be the solution to improve emotional closeness [61–63]. An example is an assignment in which students wrote weekly reflective journals about their learning and personal experiences and commented on the journals of fellow students [61]. However, it is important to note that not receiving comments or replies from fellow students on your journal or posts on the discussion board can be experienced as unfinished [58]. As for the discussion board, experience showed that students did not feel comfortable writing online about certain topics but could discuss them in class [58]. Regarding the lecturer's social presence, online asynchronous video feedback can be helpful. One of the reviewed studies showed that

hearing and seeing a lecturer during video feedback created "a sense of closeness" with the lecturer [64].

Finally, the collaborative construction of knowledge in an online learning environment while working on an assignment or assessment creates a sense of community [65]. Still, online collaboration can isolate some students, negatively affecting their motivation and enjoyment [54].

Facilitating Interaction and Discussion among Fellow Students and with the Lecturer to Stimulate Reflection and Critical Thinking

Interacting for learning can be considered as an iterative cycle of a student with a lecturer or fellow students [31] and can have varying purposes, for instance, having a social conversation, delivering feedback, or clarifying the content. In addition, in a more structured form, it can be used to discuss certain topics, encouraging the student to reflect, think critically, and understand the positions of others [32,33]. Interaction can take place face-to-face or, location-independently, online. When interacting online, there is a choice between interacting synchronously or asynchronously in time. According to several reviewed studies [42,55,58,60,61,66], these elements, that is, purpose, place, and time synchronicity, should be considered in the design of BL. For instance, if the purpose is "meeting new classmates", a better choice probably is meeting face-to-face because meeting online with new classmates was described by students as more difficult [58]. In a study about blended tutoring, the face-to-face encounters (one-to-one basis) as well as the asynchronous online exchanges with the tutor were valued by the students. Face-to-face tutoring had the advantage of direct contact with the tutor, while asynchronous online tutoring provided the students with time to think before answering the tutor's questions. The latter resulted in a deeper level of processing of the exchange and higher levels of critical thinking [60]. A comparable mechanism has been observed during in-class discussions and asynchronous online discussions. Mainly students with a deep approach to learning value asynchronous discussions for the opportunity to reflect on the topics discussed, allowing for an in-depth exploration [42,67]. Direct contact during in-class discussions allows for elaborations and spontaneous questions, ensuring a better understanding of the content [58]. Regarding online discussions, a discussion board should contain clear instructions that motivate students to explain, clarify, and support a topic [58], because superficial responses in the discussion board lead to disengaged students [58]. A student's engagement is essential because they seem reluctant to use a discussion board, probably because challenging opinions (recorded) may cause a conflict between classmates [52]. In collaborative BL, a discussion board can be part of an online collaboration environment. Besides discussion, this environment can be used for social and task-oriented interaction, thus documenting the process [52,62]. Successful experiences are using an accessible medium such as Facebook for asynchronous learning [42,61]. Incorporating asynchronous components, such as social networking and blogs, extend the learning environment and probably increase engagement [61,66].

Synchronicity in time seems to make an essential difference if it comes to learning by discussion. An asynchronous discussion provides the student with time to think and explore before formulating a reasoned reply on a discussion topic. Therefore, the term "(a)synchronous" is added to the design principle. This becomes *Facilitating (a)synchronous interaction and discussion among fellow students, and with the lecturer (. . .).*

Transforming Learning through Acquisition and Inquiry into an Active Process Based on Existing Knowledge

For learning, students use strategies compliant with their learning style [68]. Some prefer visuals, others audio or text. Different representations of content meet this diversity and help students to learn [69]. In BL, in most cases, a Learning Management System (e.g., Blackboard) handles the delivery of a variety of multimedia content—that is, video lectures [42,44,49,58,69,70], videos [45,63], interactive voice-over slides [70], instructional videos [71], an interactive online textbook [59,72], computer-mediated tutorials [60],

podcasts [51], supplemented with synchronous in-class [43,49,54,57,73,74], and online lectures [54,57]. In addition, content can be prepared and delivered by students in face-to-face and online tutorials [67]. Asynchronous online content delivery has a great advantage that it can be viewed, read, and listened to multiple times, which helps students better understand the theory [44,69,70]. Still, there is a risk that students will not immerse themselves in the material. A non-interesting video can be turned off [58]. One way to avoid such behaviour is by delivering short online presentations with attention-grabbing audio and visual components [58]. Another risk is that students do not understand or misunderstand the content delivered [44,69,70]. To verify students' understanding of the concepts, online quizzes, formative tests, or Q&A could be used [44,45,69,70]. These instruments are also useful for students with a knowledge gap [73,75]. In addition, especially used in flipped learning, the in-class meeting could be started with a quiz and review of the topics covered, resulting in a deeper conceptual understanding [73]. Although online delivery provides much more opportunities to meet the different learning styles of students, their approach to learning does not seem to change. Students with a deep or surface approach to learning in a face-to-face context show the same approach in an online context [67]. To motivate their students, a blended course about evidence-based practice and research situated learning in the professional practice environment and also provided access to learning materials at a convenient time [51]. Another strategy to stimulate the participation of students is to relate the students' own experiences with the topic/theoretical concepts of the course [69,76].

This corresponds with the programme theories about knowledge acquisition, in which the focus lies on arousing an intrinsic curiosity in the student or, as Laurillard [31] puts it, "a sense of need to know" (p. 113). This beholds that the content delivered should be relevant to the student. Relevancy of content can be achieved by aligning this content to the student's own experiences [31,33]. A learning activity suitable for activating students for knowledge acquisition is inquiry-based learning, as they have to take responsibility for their learning [31–33].

Working on Authentic Tasks with Scaffolded and Theory-Based Practice

Strategies mentioned to encourage students to work on their tasks include 1. providing a choice of assignments that match students' learning preferences [55,76], 2. supplying assignments with intrinsic feedback [58], and 3. embedding the assignments in a real-world context [52]. An example of the first strategy is an assignment that can be carried out by applying information access, interactive learning, networking, and materials development [55]. Although most students opted for information access, the students choosing networking and materials development showed more satisfaction with their work [55]. An example of the second strategy is allowing several attempts while making online assessments [58]. This reduced anxiety provided extra practice and encouraged students to explore concepts [58]. Additionally, an experiment with a dedicated interactive learning environment, involving first-year students, showed the value of instantly receiving feedback. It made independent learning possible, thus activating critical thinking skills [59]. It also exposed time management and technical problems of students, resulting in a decrease in exam grades, probably because the students in the blended section spent less time on the course materials than their fellow students in the traditional sections [59]. An example of the third strategy is a project-based course using a blended problem-based learning (PBL) design. In PBL, students build and apply new knowledge in a real-world context [52]. In this course, digital cognitive tools for documentation, argumentation, and organisation were used to scaffold the PBL process [52]. It revealed that scaffolding is essential in self-directed learning strategies such as PBL [52].

Laboratory classes need their physical surroundings. Still, there are possibilities to exercise these skills in a virtual environment. The experiences with a blended arrangement, that is, alternating virtual lab exercises with experiments performed in a physical lab, are mainly positive [71,77,78]. A virtual lab has the advantage of the possibility to repeat the exercise as much as needed. This resulted in building self-confidence among students in their knowledge and abilities [71]. Still, another experience, a chemical lab, mentions

that blended laboratory students felt less comfortable handling chemicals than traditional laboratory students and were also less convinced of the value of their learning for their professional careers [77].

A study about design studio education, supported by a real-time web-conferencing tool (synchronous mode), and Blackboard and Facebook (asynchronous mode), revealed that a physical classroom facilitates the exchange of ideas, practice and learning from fellow students and a virtual classroom, reflection on their process, and, asynchronously, researching new concepts [54].

The programme theories confirm some strategies to encourage students to work on their tasks. Ellis and Goodyear [33] advocate the design of authentic online learning tasks and tools to stimulate the transfer of learning to professional conduct. The programme theories make no mention of adapting assignments to students' learning preferences. It is added to the design principle. Especially Laurillard [31] emphasises the importance of formative intrinsic feedback.

Collaboration for Constructing a Shared Outcome through Participation and Negotiation with Fellow Students

In a flipped as well as in a blended model, collaborative working on tasks or a project motivates students to spend a great deal of time on their studies [50,53,65,69]. Collaborative learning is of particular importance if contact time is limited or in the case of a large class [69]. To improve active and collaborative learning in a digital learning environment, facilitating online interaction, project organisation, and documentation is essential [65,74]. Therefore, "in a technologically enhanced learning environment" is added to the design principle.

In BL, students with a deep learning approach, collaborating with students with a similar approach, have the most successful learning experience in academic performance as well as in using effective strategies for collaboration [74].

The programme theories emphasise the importance of learning through collaboration. The participation of students in a learning community stimulates critical reflection and discourse [31,32] and learning from each other [31]. In addition, it influences students in how they approach their work [33].

4.2. Blended Learning for Developing Students' Sustainability Competencies? (RQ2)

The realist review yielded six design principles and corresponding recommendations (Table 6 on how to design blended education. The remaining question is whether and how this BL design may support the development of sustainability competencies.

4.2.1. General Design Principles

The first design principle is about a pedagogical approach that stimulates self-regulation in a student's learning process. In a BL environment, students get more control over when, where, what, and how to learn. A virtual space adjacent to the physical space adds more spaces for discussion, conversation, exploration, acquisition, practice, reflection, and so on. In a well-designed BL configuration, balancing online and in-class activities, a student can, to a certain extent, integrate spaces, places, activities, and resources to fit his or her own needs and learns how to create and implement their learning ecology [34]. So, having more control and autonomy as well as more possibilities in time and place helps a student to develop the self-regulation skills that are essential in BL. In addition, BL utilises technological tools that can support students, for instance, by providing relevant and personalised content and assessment and tracking their learning performance [19,79,80]. Self-regulation skills are also needed in a dynamic professional environment where technological innovations, globalised competition, and environmental demands ask for flexibility, responsiveness to change [81], and a responsible attitude. To prepare a student for taking a role in such an environment not only is self-regulation important but also self-awareness of one's own values regarding sustainability issues [3]. Brundiers et al. [3] call this the intrapersonal competency and add it to the key sustainability competencies of Wiek et al. [4]. Developing an intrapersonal competency corresponds with what Biesta [82] calls "subjectivation",

meaning, awareness as an individual of "our freedom to act or to refrain from action" (p. 93). Hesen et al. [40] add, in the context of sustainability, "bound by the ecological boundaries in which this becoming occurs" (p. 86). To conclude, to be suitable for developing students' sustainability competencies, not only should self-regulation be the objective in the student's learning process but also self-awareness.

The second design principle is about fostering a safe and social learning climate. A safe learning climate can lead to students feeling free to be creative and critical and take on new challenges, unafraid of the risk of failure [40,83,84]. This feeling of freedom to express oneself is, according to Hesen et al. [40], a prerequisite in search of the self (subjectivation or intrapersonal competency) and also in collaborating while taking different perspectives into account (transboundary [18] or interpersonal competency [4]). In BL, creating a safe and social learning climate is perceived as a challenge [85]. Having to communicate in a digital learning environment, "can isolate some students detrimentally affecting their motivation and enjoyment" [54] (p. 537). Boelens et al. [85] mention several ways for lecturers to contribute to a safe and social learning climate: "showing empathy, having a sense of humour, providing encouragements, directing attention to task-relevant aspects, and attending to students' individual differences" (p. 4). In addition, several recommendations (RC6-RC11) for fostering a safe and social learning climate are extracted from the BL studies. This design principle seems equally important for BL as sustainability-oriented learning.

4.2.2. Design Principles for Applying Didactic Methods

The last four design principles are about learning methods in which students interact and discuss, acquire knowledge, bring theoretical knowledge into practice, and collaborate for constructing a shared outcome (Table 6). As presented in Section 2, living in a rapidly evolving information ecology, students need to learn how to learn. Passive knowledge acquisition during a lecture is no longer adequate and should be transformed into a more active process in which discussion, acquisition, practice, and collaboration are interwoven, according to the Conversational Framework [31]. Lecturing has a low likelihood of addressing any of the sustainability competencies [17] in contrast with a participative and research method such as project and/or problem-based learning, which can address all sustainability competencies, as defined by Lozano [17], especially, inter-disciplinary work, anticipatory thinking, critical thinking and analysis, interpersonal relations, and collaboration. Three reviewed studies present examples of how a blended design may support participative and research methods, that is, research activities based on professional practice [51], problem-based learning with additional cognitive tools for documentation, presentation and argumentation [52], and social networking, tutoring, and presentation to build content knowledge and a professional community of peers, so-called dialogic learning [86]. These blended course designs, to a greater or lesser extent, combine active knowledge acquisition embedded in the professional context, scaffolded practice and collaboration through participation and negotiation supported by a technologically enhanced learning environment. BL seems to have various possibilities to activate students' learning, but "sustainability learning requires seeking and cultivating learning environments that invite and enable people to envision alternative futures, experiment with action, anticipate different outcomes, and learn from their attempts. All these processes combined help build transformative capacity, especially the capability of individuals and collectives to bring about fundamental change." [2] (p. 71). This orientation towards change and action is missing in the BL practice studied and therefore in the derived design principles. Two examples demonstrate how technological enhancements may support transformation in knowledge, skills, and attitudes of students towards sustainability problems, challenges, and opportunities by increasing students' autonomy to direct their own learning. Sibbel [39] describes the online development of students' knowledge management skills (capture, interpretation, integration, and reconstruction), supported by face-to-face interactions, applied in cycles of collection and sharing, encouraging (peer) feedback, and self-reflection to create awareness of personal attitudes and values. Archambault and Warren [24] describe a blended course

design for future educators, in which digital storytelling techniques are used to stimulate students' engagement and knowledge acquisition of sustainability issues, followed by in-class discussions on how the content can be implemented in their future classrooms. Both courses aim to bring about sustainable change in personal attitudes and values for one [39], and professional practice for the other [24]. In both designs, in-class sessions were used for discussions. Critical thinking skills and in-depth exploration could have been encouraged if these synchronous discussions had been accompanied by asynchronous discussions online [67]. To conclude, to emphasise transformative learning, two design principles of BL should be adapted. Knowledge acquisition should not only be based on existing knowledge but also on constructing new knowledge contributing to sustainable change and while bringing this knowledge into practice, the corresponding tasks should not only be authentic but also action-oriented.

The last design principle, collaboration for constructing a shared outcome through participation and negotiation with fellow students, is a commonly used learning activity in BL to motivate students (RC5). Participative learning methods are also mentioned as appropriate methods for sustainability-oriented learning [17,38,87] because collaboration is a contingency to develop interpersonal competency [4]. As a key component of this competency, Wiek et al. [4] mention "the capacity to understand, embrace, and facilitate diversity across cultures, social groups, communities, and individuals" (p. 211). A digital learning environment can easily facilitate this diversity in collaboration activities without having to travel, so at low costs [18]. In sustainability-oriented education, interpersonal competency is connected to all other key competencies [3]. To realise this, a collaborative approach should use the aforementioned disciplinary and cultural perspectives to address complex social, ecological, technical, and other problems to bring about transformative change [88]. The inter- or transdisciplinary way of collaborating is not mentioned in the review studies and should be integrated into the design principle. Table 6 contains the adapted design principles together with the recommendations from the realist review.

Table 6. Design principles for sustainability-oriented BL. In italics: additions to support sustainability-oriented learning. Context can be traced back in the context Table A1 (Appendix A).

Design Principle	RC nr	Recommendations (RC) from the Realist Review
Aiming at self-regulation *(and self-awareness)* of learning and practice in the student's learning process	RC1	Students start their BL experience with different levels of self-regulation [43] as well as dealing with the digital learning environment [48]. Therefore, the organisation of the BL unit should be properly introduced to the students at the beginning [48]. In addition, the communication about study and submission expectations should be clear throughout the learning unit [43,46,48,49].
	RC2	The learning process of the student can be supported by the lecturer by delivering direct feedback on their performance [47]. Feedback can also be provided through online tests and quizzes [50]. Online (formative) tests provide students with insights into their learning process and encourage the student to study regularly [50]. Additionally, a digital learning environment using learning analytics can generate warnings to the students if they spend insufficient time on their work [49].
	RC3	To motivate students, the presence of the lecturer should be apparent throughout the BL unit in supporting the students, in class as well as online [44,47,51].
	RC4	Give the students opportunities to compare their work with the work of fellow students. This increases motivation and positive competition [54].
	RC5	Motivation to spend a great deal of time on the required tasks increases when students are working in teams [47,53,88].

Table 6. *Cont.*

Design Principle	RC nr	Recommendations (RC) from the Realist Review
Fostering a safe and social learning environment	RC6	Organise at the beginning of the BL unit opportunities to get to know one another during an in-class meeting, because meeting online with new classmates is experienced as more difficult [58].
	RC7	Provide opportunities for students to interact with each other during in-class meetings to create an atmosphere of mutual attention and warmth [51,57,60].
	RC8	Emotional closeness and personal ties among students can be promoted by creating opportunities for informal online interaction (social networking, blogs) [61–63].
	RC9	A lecturer may consider delivering complex feedback through a video recording to a student. This is conducive to a feeling of connection with the lecturer [64].
	RC10	The lecturer should monitor online discussion platforms to ensure that everyone's views are treated with respect [58].
	RC11	Online collaboration can isolate some students, so regular coaching of a lecturer is necessary [54].
Facilitating (a)synchronous interaction and discussion among fellow students and with the lecturer to stimulate reflection and critical thinking.	RC12	Take different approaches to learning into account by providing the opportunity to discuss topics synchronously as well as asynchronously [58,67].
	RC13	Provide clear instructions to online discussion boards to encourage meaningful responses [58].
	RC14	The lecturer should consider if s/he delivers feedback synchronously or asynchronously to the student. Asynchronous delivery provides the student with the opportunity to consider the feedback given and to correct their work [60,64]. In addition, through asynchronous online tutoring students reach higher levels of critical thinking due to having more time to process the student–tutor exchanges [60]. Synchronous face-to-face tutoring may result in a dialogue in which a student gets the opportunity to develop communication skills [86].
	RC15	Provide an online collaboration environment for social and task-oriented interaction, thus, organising discussions and documenting the process [52,61,66].
Transforming learning through acquisition and inquiry into an active process based on existing knowledge ***(in which new knowledge is constructed to contribute to sustainability)***	RC16	Support students' preferred learning strategies by providing different representations of online content, for instance, a video lecture, an interactive online textbook, or a podcast. Videos should be short with attention-grabbing audio and visual components [44,58,69,70].
	RC17	Embed the topic of the course in the students' own experiences and contextualise it to real-life situations to stimulate participation in the learning activity [51,76].
	RC18	Offer, in a flipped approach, not only video recordings of lectures, but also organise opportunities for students to verify their understanding of the concepts (online tests, Q&A) [44,45,69,70]. In addition, the in-class meeting could be started with a quiz and a review of the topics covered [73].

Table 6. *Cont.*

Design Principle	RC nr	Recommendations (RC) from the Realist Review
Working on authentic *(and action-oriented)* tasks with scaffolded and theory-based practice meeting the learning preferences of students	RC19	To encourage students to work on their tasks, give students a choice between different assignments to meet their learning preferences [55,76].
	RC20	Provide assignments containing formative intrinsic feedback (tests, video, FAQ). This reduces anxiety and provides extra practice [58].
	RC21	In design studio education, a physical classroom facilitates the exchange of ideas, practice and learning of fellow students and a virtual classroom, reflection on the process, and, asynchronously, researching new concepts [54].
	RC22	Give in preparation for a laboratory class an online simulation product or video. Students can build self-confidence in their knowledge and abilities and increased engagement [71,78].
***(Inter/transdisciplinary)* Collaboration for constructing a shared outcome through participation and negotiation with fellow students in a technologically enhanced learning environment**	RC23	Mix students with a surface and a deep approach to learning so that all collaborative groups have at least one or two stronger partners [74].
	RC24	The digital learning environment should support collaboration, that is, support of interaction and project organisation as well as documentation [52,65].

5. Discussion and Suggestions for Future Research

Key design principles and associated recommendations have been developed to guide the design process of a BL unit supportive to develop students' sustainability competencies. As a first step, design principles and recommendations were extracted from the BL practice in general, answering the first research question. Similarities and differences have been unravelled by mirroring these principles against sustainability competencies and the corresponding pedagogical approach, corresponding to the second research question. This section discusses the most important features of these design principles as a result of answering the two research questions and, if relevant, accompanied with directions for further research.

At first glance, the guiding principles seem to be rather generic and relevant for higher education in general, but the given directions are crucial in BL and they can also be valuable in informing sustainability-oriented education, because self-regulation, community building, interaction and discussion, knowledge management, and collaboration have been identified as critical in students' learning around wicked sustainability problems [17,18,38,87]. In a high-quality BL design, the added virtual space can enhance sustainability-oriented learning by enabling self-directed learning, (a)synchronicity in time and place-independency. Regarding self-directed learning, digital technology can engage an individual student in acquiring (reliable) knowledge and understanding of sustainability issues through multimedia content delivery [24] and tools for feedback and assessment [39]. Making use of the advantages of (a)synchronicity in time enhances the reflection and critical thinking skills of students [42,60,67,86]. Lastly, place-independency creates possibilities to facilitate incorporating different disciplinary, cultural, and social perspectives in collaboration activities [18]. This inter- or transdisciplinary approach of collaboration could be one of the affordances of BL, but it represents also one of the omissions in the BL practice studied. Further research is needed on how inter- or transdisciplinary collaboration can reach its full potential in a blended design.

Although all design principles are essential, one principle in particular requires more attention and that is *Fostering a safe and social learning environment*. The forced online learning modus during the COVID-19 pandemic has led to a negative impact on students' performance and well-being [89,90]. Several academic studies have studied this impact. A search in Google Scholar with the search term "emotional well-being COVID-19 online

learning "higher education" resulted in 44,600 hits (accessed 24 February 2023). The emotional well-being of students has not been explicitly included in *Fostering a safe and social learning environment*, and probably a study of the aforementioned post-COVID-19 studies can add recommendations to fill this gap.

Transformation to a sustainable world needs "change agents", who are aware of what they can or want to change and know how to take action for implementation [3]. Two BL designs demonstrate how this can be achieved [24,39], but it is not common practice in a BL design. To create this self-awareness and transformative capacity, action-oriented methods are supportive, such as environmental place-based learning and community-oriented service learning. Opportunities to facilitate this by BL probably lie in creating value for the local community [91] or experiencing the surroundings through a virtual augmented reality platform [92]. This could also be employed as a preparation or follow-up activity for a field trip [93]. Further research into these opportunities is recommended.

Although the aforementioned Integrative Relational Framework, a term we coined to describe the theoretical vantage point provided by Ellis and Goodyear [33], seems to align well with recent work on sustainability-oriented learning [2], this perspective did not surface prominently in the papers reviewed. Therefore, some additions to the design principles have been proposed, and the integral utilisation of these guiding principles might well lead to a more ecological or relational perspective on educational design in higher education, especially in universities seeking to become more relevant, responsive, and responsible in light of current and emerging global challenges.

Lastly, a high-quality ecological BL design can also help HEIs in walking the talk in reducing a part of their travel-related carbon footprint. While this seems somewhat disconnected from this study, this is an essential aspect of a whole-institution approach to sustainability [94], where universities need to become living practices of sustainability.

Research Limitations

A single researcher conducted the collection and analysis of data by applying a realist review methodology. It is possible that alternative decisions would have been made if another researcher had been involved or if a team of researchers had collaborated to reach a joint consensus. However, the subjective nature of decision-making was mitigated by the iterative process of our realist approach, which compelled the researcher to repeatedly re-evaluate previous choices across multiple stages. The review protocol itself and the interpretation of the data were discussed in regular sessions with others.

The aim of the realist review, to explore "what works for whom, in what circumstances, in what respects, and how", cannot be met for all that is possible with BL. Therefore, we applied a pragmatic approach. The initial design principles are not evaluated in the empirical evidence as a whole but in parts. It provided an overall picture of the focus areas in BL and how they are dealt with in practice. To validate the effectiveness of the complete set of pedagogical design principles in a blended design, more research is needed.

There is a plethora of research available about BL. In this research, 38 studies are used after an extensive search in multiple libraries, but inevitably, interesting studies on the subject have been overlooked, especially those not published in the selected databases, including studies published in other languages than English.

Although all design principles are essential, one needs more attention and that is *Fostering a safe and social learning environment*. The forced online learning modus during COVID-19 has led to a negative impact on students' performance and well-being [90]. Several academic studies have researched this impact. A search in Google Scholar with the search term "emotional well-being COVID-19 online learning "higher education" resulted in 44,600 hits (accessed 24 February 2023). The emotional well-being of students has not been explicitly included in *Fostering a safe and social learning environment* and probably the aforementioned post-COVID-19 studies can add recommendations to fill this gap.

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Appendix A

Table A1. Context of the empirical studies about a BL intervention.

Reference	Participants		Subject	Didactic Method
	(Average) Age	Study Phase		
[53]	20	Undergraduate	English, International Business	Flipped learning, project-based learning
[64]			Technology integration courses	Video feedback
[50]			Engineering, Introductory programming	Team-based learning/online web communities
[76]			Teacher Education Program of Elementary Education	In-class learning + online activities such as virtual class, forum, blog page
[71]	19		Practical skills training for agricultural education	Virtual and physical lab
[77]		First-year	Introductory chemistry	Virtual and physical lab
[63]		First-year	Laboratory course	In-class + online activities such as instructional or self-video, peer feedback, blog
[69]		Third year	Entrepreneurship course	Flipped learning, group project
[56]	19	First-year	Information Technology	Gamification
[75]		First-year	Mathematical Methods for Engineers	Choice of amount of blending, supported by videos and interactive and communication tools
[42]	19–21	Undergraduate	Communication and presentation skills	Flipped learning, video-based lectures, in-class discussions followed by online discussions of sustainability topics via Facebook
[78]	23.4	Undergraduate	Biology	Physical and virtual lab
[57]	20–22	Fourth year	Child and Youth capstone course	Interrelated academic activities ranging from analysing video-based material to reading research papers
[48]			17 blended courses	Blend: 20 to 80% weekly class time conducted online
[60]			Writing and defending thesis	Blended tutoring
[65]		Third year	Experimental Psycholinguistics	In-class learning combined with collaboration activities supported by Web 2.0 technologies
[43]		Second-year	ICT in teaching and learning	In-class learning + online activities such as assignments and forum
[70]		Undergraduate	Medical Sciences	Flipped learning: online modules with quizzes to be completed before in-class session
[44]		First-/second year	Biology	Video lectures with guiding questions and quizzes + in-class learning + physical lab
[73]			cardiovascular physiology	Flipped learning: online learning modules assessed at the beginning of in-class session (problem solving assignments)

Table A1. *Cont.*

Reference	Participants		Subject	Didactic Method
	(Average) Age	Study Phase		
[45]	19–45		Special education	Flipped learning: online videos, in-class discussions, group projects
[46]	21.5	11.9% sophomores, 35.6% juniors, and 50.8% seniors	Hospitality management, leisure services	Flipped learning: online textbook with PowerPoint, in-class group work and discussion
[49]		Juniors and sophomores	Life science	Flipped learning: online videos and documents assessed at the beginning of in-class session (discussion)
[47]	20	Second-year	Building business-quality websites	Collaborative learning
[67]		Third year	Social sciences course	Discussion in-class and online
[62]		First-year	English	Collaborative communication. Discussion groups
[58]			hybrid courses	Online: lectures and assignments for diverse learning styles, in-class discussion, and collaboration
[51]		First-year	Research, Evidence and Clinical Practice	Experiential situational learning, research
[86]		Fourth-year	Education	Dialogic learning
[55]		Sophomores	Digital Citizenship	Online activities according to student's learning style
[54]		Third-year	Architecture course design	Virtual design studio and in-class activities
[72]		Graduate	Introduction to American Government	Interactive online textbook
[52]	23–28	Post-graduate	Project management	Problem-based learning
[59]		First-year	Introductory Psychology	Textbook + virtual lab
[95]		All years	Introductory Microbiology	Flipped learning: online lectures assessed at the beginning of an in-class session
[66]		Undergraduate	Marketing course	In-class sessions complemented by asynchronous discussions using Facebook
[74]		First-year	Introduction to human biology	Teamwork
[61]	24–45		Understanding and Utilising Web 2.0 Tools for Education	Blended learning using blogs for interaction and reflection

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