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Design-based education, sustainable teaching, and learning
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Abstract: Societal developments necessitate the continuing development of higher education, as labor markets are in full swing and professions are shifting in orientation or sometimes disappear completely. Therefore, a concomitant goal of higher education should be to help students develop metacognitive skills and domain-specific knowledge and skills. For many years, competence-based education and problem-based learning have dominated higher education. In this article, an overview of the principles and development of these concepts is given. Subsequently, based on self-regulation theory, approaches to learning and the demands of our society to learn how to face wicked problems, a sustainable approach to teaching and learning are outlined in this conceptual article. The multiple layers from which a sustainable learning environment should be built provide guidance for instructors during the design of their educational practice. Practical implications for educators to approach the transition to sustainable learning environments are given in the form of questions that can shape the dialogue on sustainable education.

Subjects: Study of Higher Education; Teaching & Learning; Theories of Learning; Sustainability Education, Training & Leadership

Keywords: learning environments; approaches to learning; sustainable teaching; sustainable learning; self-regulation

Higher education aims to prepare students to successfully enter the labor market, which is changing rapidly due to, for example, technological developments. Consequently, new professions arise and other professions disappear, and it is no longer realistic to expect that knowledge gained...
in initial education will last for a lifetime (Kirschner, 2017). Further education will necessarily occur multiple times throughout life, emphasizing the importance of acquiring metacognitive skills (reflecting on learning processes, monitoring progress toward goals, etc.). Therefore, an important goal of higher education is to support students to gain control over their own learning, help them develop skills and apply strategies to take the lead, and educate students in such a way that they become self-regulative learners, resulting in a lifelong, sustainable impact on their personal and professional development.

However, (higher) education learning environments are not always conducive to this concept. The development of metacognitive skills is important to initiate a sustainable process of development to be successful during and after study. To enhance the learning environments in higher education, it is important to consider other forms of learning in which metacognition (knowledge about and regulation of one’s cognitive activities in learning processes; Flavell, 1979) is developed in new and authentic situations. The transition of learning environments into environments in which other forms of learning can be developed should consider “what students do and why they do it.” The constructs of metacognition (e.g., self-regulation) and approaches to learning are strongly related; even though they have different research traditions, they both address “the will and the skill,” or “intentions and strategies” (Heikkilä & Lonka, 2006).

To provide students with the optimal conditions to prepare themselves to function in society, higher education systems must change. Traditional universities are less ready for this, but universities of applied sciences (UAS), which offer all types of training programs that lead to an associate, bachelor's, or master's degree, are more flexible in changing their curricula and approaches. The assumption accelerating these changes is that learning environments that are more aligned with the “real world” better prepare students. Alignment with the real world is achieved in a learning environment that stimulates the learning processes directed at the development of metacognitive skills and addresses the will and skill/intentions and strategies. In other words, a sustainable learning and teaching approach. This article describes the process of development toward sustainable education (i.e., learning and teaching), elaborated as design-based education in higher education in the Netherlands. A model of multiple layers of the learning environment is presented to provide scaffolding for teachers while designing and evaluating the learning environments of their programs.

1. Learning and learning environments

Biesta (2015) stated that education is a dialogical process. Learning and teaching means communicating and jointly giving meaning to elements in our environment. Biesta also stated that learning cannot be forced and that teaching is the facilitation of learning. This means that designing aligned learning environments are critical success factors for students. Wiliam (2011) formulated the job of teachers as follows: “It is to engineer effective learning environments for the students. The key features of effective learning environments are that they create student engagement and allow teachers, learners, and their peers to ensure that the learning is proceeding in the intended direction.”

An important part of Biesta’s reasoning is based on the work by Dewey (1916), who described communication as the process of sharing experience until this experience becomes common property. Furthermore, “a person can only learn by letting the quality of things influence the mind through the senses. Once a number of sensory impressions has been acquired, associations or another powerful process of mental synthesis should shape them into ideas—into objects with meaning”. Although Dewey did not formulate a (social) constructivist learning theory, his views on the communication elements of social constructivism are recognized, and they form often the basis of the view on higher education. Vygotsky (1978) is often considered the founder of social constructivism, as he said that knowledge is constructed by dialogues and in interactions with others. He argued that knowledge is co-constructed in a social environment and that during this process of social interaction, people use language to confer meaning to that environment. The use
of language between individuals in an environment—an inter-psychological tool—is at the center of the social constructivist philosophy on the learning process. Successful learning then results in an internal dialogue—an intra-psychological tool—that can be applied in various future situations. Thus, according to social constructivism, knowledge is constructed together with others, while learning is an internal mechanism that occurs inside the individual (Churcher, Downs, & Tewksbury, 2014). In higher vocational education in the Netherlands, this learning theory has been applied in many programs, resulting in educational concepts such as competence-based education and problem-based learning (and variants such as project-based and case-based education).

2. Competence-based and problem-based learning as a didactic elaboration of social constructivism

2.1. Competence-based education

In the 1960s and 1970s, interest in competence-based education grew in the context of organizational training in the U.S. (Biemans, Nieuwenhuis, Poell, Mulder, & Wesselink, 2004). At the time, competence-based education was defined as “a form of education that derives a curriculum from an analysis of a prospective or actual role in modern society and that attempts to certify student progress on the basis of demonstrated performance in some or all aspects of that role” (Grant, 1979). Competence-based education addressed the need for students to apply knowledge in practice instead of only accumulating knowledge. The changing society, the need to learn how to learn, and the increasing amount of information encouraged programs in higher education to shift to competence-based designs. The Bologna Declaration (1999) also pointed in the direction of a shift from teaching knowledge to teaching competence (Koenen, Dochy, & Berghmans, 2015).

For many years, UAS in the Netherlands have designed their learning environments to be competence-based. These learning environments are presented in Figure 1.

The figure demonstrates that educational programs are designed for specific domains, such as economics, teacher education, or technology. Students often work on assignments in simulated contexts that represent their future professional fields. To execute the given tasks, they require knowledge and skills, and gaining knowledge and developing skills are explicit parts of a competence-based learning environment. Subsequently, they learn how to apply the knowledge and learn strategies to solve problems. As an outcome of the learning process, students deliver a professional product, for example, a marketing report or a lesson design, and display professional behavior.
Most of the learning environments in the Netherlands are based on these concepts and are directed at achieving the learning outcomes in terms of delivering a professional product and developing and displaying professional behavior. Over the years, competence-based education has been executed in different ways, and it may not always be explicitly clear if, when, and how programs are designed as competence-based programs. The underlying principles are often similar, such as co-construction of knowledge and self-directed learning, without labeling educational programs as competence-based. A clear definition of the concept of competence is not available in the literature, but in a study by the Dutch Education Council, six common characteristics of competencies were extracted from the literature: competencies are context-bound, are indivisible (knowledge, skills, and attitudes are integrated), are subject to change, are connected to activities and tasks, require learning and development processes, and are interrelated (Biemans et al., 2004; Van Merrienboer, van der Klink, & Hendriks, 2002).

**2.2. Problem-based learning**

Since its first implementation in 1969, problem-based learning (PBL) has had a rich international history. More than 40 years ago, the U.S. urgently needed to develop its medical educational programs—which were seen as ineffective and not student-friendly—into student-oriented, multidisciplinary programs aimed at promoting lifelong learning (Boud & Feletti, 1997). There were several reasons why it was not effective to provide medical professional knowledge separately. Students did not develop an accurate image of the future professional practice and only learned to apply the acquired knowledge to a very limited extent. In addition, both medical knowledge and practical applications were developing rapidly. Another important observation was the lack of students’ motivation to attend traditional classes and acquire the required knowledge. These initial reasons for organizing education differently are recognizable and still applicable today. Rapid changes in theory and practice also occur in many different disciplines in the 21st century. Many social issues require a multidisciplinary approach, for example, the need for economic growth and the need to make this growth sustainable. Student motivation remains a major challenge for educators. The original objective of problem-based learning is both clear and still current after 40 years. PBL has its roots in the medical academic world but has been applied worldwide at various educational levels and in many disciplines (Barrows, 1996; Hallinger & Lu, 2011; Schmidt, van der Molen, Te Winkel, & Wijnen, 2009; Smith, Sheppard, Johnson, & Johnson, 2005; Walker, Bridges, & Chan, 1996).

Savery (2015) defined PBL as “an instructional (and curricular) learner-centred approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Critical to the success of the approach is the selection of ill-structured problems (often interdisciplinary) and a tutor who guides the learning process and conducts a thorough debriefing at the conclusion of the learning experience.” Although PBL has its roots in educational practice, a scientific foundation has been developed to clarify the mechanisms underlying it. Dolmans, De Grave, Wolfhagen, and Van Der Vleuten (2005) described the four learning principles that form the basis of PBL: (1) constructive, (2) self-regulated, (3) collaborative, and (4) contextual learning. Constructive learning implies that learning is an active process during which students construct knowledge. Personal experiences and interactions with others give rise to an individual interpretation of the world. Existing knowledge is activated by discussions, answering questions, and taking notes, while new information can be linked to existing knowledge. According to Dolmans and many others, the active participation of students can lead to the activation of existing knowledge. The second principle, that of self-regulated learning, is focused on the planning, monitoring, and evaluation of the learning process. The activation of existing knowledge is an important condition for starting this process. Based on that, students can set objectives, plan, and subsequently monitor the progress of their learning processes. The third basic principle of PBL is collaborative learning. Collaborative learning can only take place if there is a shared objective, shared responsibility, and interdependency and if learners can agree by open communication. Finally, according to contextual learning, learning always occurs within a context.
The situation in which knowledge is acquired affects the application of that knowledge. The transfer of acquired knowledge to new, unknown contexts does not happen automatically but can be stimulated by approaching problems/situations from different perspectives.

By examining these four principles, one may consider whether there is a need to develop various versions of PBL for a variety of domains or whether a “one size fits all” version will do. Let’s take contextual learning as a starting point to answering this question. The context of education in higher professional education reflects the future professional practice, which is different for each discipline. The differences can be illustrated by the various professional products defined in the report of the expert group Protocol (2014). The report describes five professional products that are dominant in a profession (Losse, 2012, in expert group Protocol; 2014): an advice, a design, an end product, an action, and an investigation. These professional products can range from financial advice to therapy and forensic investigation. This demonstrates that the objectives set in higher education are diverse. The intended goals may be expressed in an emphasis on obtaining an extensive repertoire of knowledge or on the development of specific professional skills. The intended learning outcomes steer the design and implementation of learning environments (i.e., alignment; Biggs, 1996). This results in a design of learning environments as well as the assessment of knowledge, skills, attitudes, and competences that align with the intended learning outcomes. In other words, the required alignment leads to different PBL designs.

These examples show how the intended outcomes of the program—the delivery of a certain type of professional product as defined by the expert group Protocol—leads to considerable variety in the design and implementation of PBL. The need for variety in the design of a PBL curriculum, resulting from various contexts and goals, is essential for higher professional education programs. This line of reasoning also applies to competence-based learning environments. By allowing the professional field and national and international societal developments to affect the design of learning environments, education becomes robust.

2.3. Competence-based education and problem-based learning in transition to sustainable education

Competence-based education and problem-based learning are directed at a student-centered approach to teaching and learning and are underpinned by social constructivism, collaborative, contextual, and self-directed learning. However, there are concerns whether competence-based education and problem-based learning give sufficient attention to the context and the problem, the question, and the innovation that is central in that specific context. Or put differently, how to approach so-called wicked problems that cannot be defined because they continue to change when they are studied (Ramaley, 2014). We previously stated that contextual learning legitimizes the need for diversity in PBL and competence-based education (i.e., learning environments). The focus on contextual learning is the starting point for critically examining whether PBL and competence-based education go through all the phases necessary to come to a solution, an answer, or a design. Do PBL and competence-based learning environments provide enough attention to the user (i.e., the client, the customer) to analyze the problem from several perspectives and to test and evaluate the solution/prototype to determine whether the chosen solution really meets what the customer wants? Since the early 1990s, the creative industry has operated according to the principles of design thinking (Van der Hoek, 2015). This philosophy takes the client’s view as the main starting point for solving a problem. This is also called empathy for the problem, the client, and the environment. The principles of design thinking add an essential element to PBL and competence-based education by creating a stronger focus on the complex questions from the professional field. Important characteristics of design thinking are a focus on the environment and humans, engagement, an iterative cycle that provides space for experiments, creativity, thinking out of the box, and prototyping (Rauth, Köppen, Jobst, & Meinel, 2010). The multidisciplinary approach and phases of design thinking (such as understanding, defining, ideating, designing, applying/experimenting,
evaluating, and improving) tie in well with innovation, finding solutions for complex issues, and creating valuable new ideas, products, or services. It is also about learning by experimenting and doing and learning from experiences and mistakes. Feedback, evaluation, reflection, and adjustment form natural elements of the cycle. As such, design thinking is closely interwoven with learning processes. The characteristic aspect of design thinking is its iterative nature, which means experimenting, developing and reviewing prototypes and taking certain steps more than once and in no particular order. All stakeholders (students, teachers, and working field) participate in this iterative, collaborative learning process.

It is remarkable to see that competence-based education, PBL, and design thinking all have their roots in daily practice. Developments such as the shift from teaching knowledge to teaching competence (competence-based education), the shift to student-oriented, multidisciplinary programs aimed at life-long learning (PBL), and in the non-profit business sector (design thinking) started by examining what students and the professional field needed to develop optimally. The need for (further) development of higher education led to a fusion of PBL, competence-based education, and design thinking, resulting in a more balanced and complete sustainable educational concept. In PBL and competence-based education, the student is central, and in design thinking, the working field is central. The transition to new, unknown situations, both during studying in higher education and while working in the working field, requires the development of lifelong (i.e., sustainable) learning goals.

The developments in Dutch higher education (i.e., the historical story line) is determined by the development from competence-based education and problem-based learning (and variants thereof) into education that has explicitly sustainable goals. These sustainable goals are aimed at the development of metacognition. When the principles of higher education in terms of competence-based education and problem-based learning are brought together with these sustainable goals (i.e., development of metacognition), they can be summarized in several principles of a sustainable approach to learning and teaching (Geitz, 2016).

(1) Sustainable education is based on social constructivist, contextual, self-regulated, and collaborative learning and assumes empathy for the student, the lecturer, and the environment, with iterative processes being deployed to solve complex issues from the professional field.

(2) Sustainable education is focused on the changing demand from the professional field and takes national and international developments into account.

(3) Sustainable education is aimed at developing the adaptability of students in learning environments in which an effective, efficient, and sustainable learning process is initiated.

(4) Sustainable education is aimed at the construction of a solid foundation of knowledge, at the skill to transfer knowledge to unknown situations, and at the development of metacognition.

(5) Sustainable education is a reflection of the complexity of the macro and meso environments and shapes students’ learning environments with optimal alignment of the various elements.

(6) Sustainable education results from the relationship between the lecturers, students, and the professional field. Alignment and perception have a significant impact on this relationship.

As mentioned, Biesta (2015) defined education as a dialogical process. However, sustainable learning and teaching is a triological process—a trialogue between students, lecturers, and professional fields. This trialogue assumes an environment in which it must be possible to continuously find alignment between the actors and in which mutual relationships and collaboration are of great value. The trialogical process has many dimensions, and the alignment of these three parties must be aimed for while developing sustainable education.
3. Design-based education: redesign of learning environments

Design-based education (DBE) is a further development (i.e., redesign) of the existing concepts of problem-based learning and competence-based education on the basis of the principles of sustainable education. Innovative elements are added to these two concepts to design a sustainable educational concept—a learning environment in which an effective and efficient learning process is stimulated and sustainable goals can be achieved and an ambitious learning climate that challenges students and offers room for talent development and profiling. Formal and informal learning are increasingly intertwined.

Social constructivism is an important foundation for the DBE learning environment. To offer students the opportunity to learn in interactions with others, students spend a large part of their time in ateliers (i.e., a space—physical or online—in which students spend a substantial part of their time working on authentic assignments). In these ateliers, students work together with teachers and the working field to solve issues occurring in that specific professional field. They face these problems by applying iterative, methodological phases inspired by the principles of design thinking. Based on these principles and the intended goals of sustainable education, six phases of the DBE process have been identified.

The six phases are:

1. research the question
2. define the core problem
3. generate ideas
4. design prototypes
5. test prototypes
6. research and improve

These phases are depicted in Figure 2. The circle and the six DBE phases might give the impression that the way of working is linear. However, that is not always the case, as a distinguishing feature is the iterative process of the design-based way of working and learning.

The dark gray boxes indicate which phases are already integrated in PBL and competence-based education. Phase 1 is to a certain extent integrated, both in PBL, as competence-based education students face problems/questions related to their domain of education (i.e., their future working
field). However, in design-based education, phase 1 is more intense. Students have to dig in much deeper to determine what the question/problem is. They have to approach this phase from an empathetic perspective. Phases 5 and 6 (in light gray) are not often integrated in PBL and competence-based programs but are explicitly added to design-based education to educate students in a more sustainable way. Based on the principles of design thinking, these are necessary phases. Students must learn to look critically at the prototypes/designs/solutions they find for the specific question. They have to learn to research the effects and adjust their prototypes, which are all essential phases to continuously face difficult problems and questions. Furthermore, these phases add value to the learning process of developing metacognitive skills and gaining metacognitive knowledge. Reflection on the phases whilst researching the effect of the solution/prototype is an essential skill in becoming a self-regulating learner.

4. Design-based education and self-regulated learning

The six DBE phases can be related to the phases of self-regulated learning. Self-regulated learners are described as being able to set task-related, reasonable goals, take responsibility for their learning, and maintain motivation. In addition to these characteristics, these learners are assumed to be able to vary in their cognitive and metacognitive strategies and are able to monitor and adjust their strategy use (Heikkilä & Lonka, 2006). Zimmerman (2002) distinguished the components of self-regulated learning as setting goals, adopting strategies, monitoring progress, restructuring one’s physical and social context, managing one’s time, self-evaluating one’s methods, attributing causation to results, and adapting future methods. Zimmerman (2002) proposed a model in which three phases of self-regulation processes are included: the forethought phase, the performance phase, and the self-reflection phase (see Figure 3). These phases occur before, during, and after learning. Before learning (i.e., forethought phase), task analysis and self-motivation beliefs play an important role in enhancing self-regulative behavior in students. Goal setting, strategic planning, and self-efficacy beliefs influence self-regulating behavior positively. During learning (i.e., performance phase), self-control and self-observation methods support students in becoming more self-regulative learners, and finally after learning (i.e., self-reflection phase), self-judgment and self-reaction contribute to this self-regulative cycle. Self-regulated learning is a complex phenomenon that has been researched extensively, resulting in several models representing the phases and characteristics of self-regulation (Andrade & Cizek, 2010). In acknowledgment of the many different models representing self-regulation, Zimmerman’s model provides a sound basis for considering the intended learning process in a DBE learning environment from a self-regulatory perspective.

Figure 3. Three phases of self-regulation, adjusted (Zimmerman, 2002).
The fundamental idea of Zimmerman’s cyclical reasoning is that the various phases influence the subsequent phase. Several studies reported high correlations among learners’ use of the forethought, performance, and self-reflection phase processes (Zimmerman, 2002; Zimmerman & Kitsantas, 1999).

This cyclic reasoning in terms of self-regulation can be applied to the cyclic and iterative reasoning of design-based education as well (see Figure 4). Before starting a research/learning process to approach a problem, goal setting, planning, and managing one’s motivational beliefs are necessary processes influencing the effectiveness of the execution of this research/learning process. Furthermore, during the research/learning process, the application of strategies to effectively approach and execute the research (i.e., learning) supports the intended outcome of the process. Finally, after the initial research steps resulting in a solution/prototype, self-reflection is needed to determine whether the intended outcome/ performance is recognized and valued by knowledgeable others (i.e., working field and lecturers). Self-reflection leads back to the forethought phase that precedes the next learning efforts (Andrade & Cizek, 2010).

The sustainable approach to teaching and learning in design-based education is thus embedded in the concomitant processes of DBE and the phases of self-regulated learning. Whilst designing a DBE learning environment (i.e., a sustainable learning environment), the learning activities, strategies, feedback, guidance, and assessment should be aligned with these phases.

Heikkilä and Lonka (2006) stated that even when learning environments are designed to promote self-regulated learning, students might perceive these environments differently. On the one hand, students might perceive these environments as motivating and stimulating; on the other hand, students may interpret these environments as threatening. Thus, it is important to continuously monitor the strategies students use and to provide sufficient instructional scaffolding.

Problem-based learning and competence-based education aim for two learning outcomes: delivering a professional product and displaying professional behavior. In design-based education, a third intended learning outcome is metacognition. The rationale for this outcome stems from the statement outlined in the introduction of this article: the need to prepare students for lifelong development.

### 4.1. Approaches to learning and self-regulation to scaffold design-based education

Reasoning from a sustainable approach to learning and teaching design-based education is directed at developing metacognitive skills and knowledge in students. As stated previously, the constructs of
metacognition and approaches to learning are strongly related; even though they have different research traditions, they both address “the will and the skill,” or “intentions and strategies” (Heikkilä & Lonka, 2006).

The research tradition of approaches to learning began in the 1970s with Marton and Säljö’s (1979) distinction of two approaches: deep and surface. Marton and Säljö’s phenomenographic research provided an understanding of how students approach learning. They studied how students perceived and executed a reading task and found that students approached the task with varying intentions. Some students intended to understand the meaning of the text. Others mainly wanted to reproduce the words they had read in case they were asked to do so. Students who intended to derive meaning from what they had read also tried to relate the information to previously acquired knowledge, to structure ideas, and to critically evaluate the knowledge and conclusions presented in the text. The students who intended to remember the text generally displayed a different learning strategy characterized by the intention to reproduce content by deploying learning processes such as memorization. Marton and Säljö defined the different approaches as deep learning and surface-level learning. This conceptual framework is known as “student approaches to learning.” Deep learning is characterized by the intention to understand the content and the deployment of learning processes aimed at relating and structuring ideas, the search for underlying principles, analysis of relevant proof, and critical evaluation of knowledge (Biggs, Kember, & Leung, 2001; Entwistle & McCune, 2004; Lonka & Lindblom-Ylänne, 1996; Loyens, Gijbels, Coertjens, & Côté, 2013). Therefore, deep learning and surface-level learning are seen as intentions/motives, together with the accompanying learning activities.

However, it is important to approach the two learning strategies critically. The terms deep and surface-level learning could easily lead to unwanted and unfounded conclusions about students. Such conclusions could involve implications about their personality and attribute a certain value to it. In this regard, it is important to realize that various factors in the learning environment stimulate deep or surface-level learning (Biggs et al., 2001). Deep and surface-level learning are the result of the set-up of the learning environment rather than a personal characteristic. Recently, the term “unreflective approach” has been suggested to describe surface-level learning, referring to students whose study processes are unreflective, and the outcome is fragmented knowledge (Lindblom-Ylänne, Parpala, & Postareff, 2018).

Students who apply the deep approach pay attention to the fundamental idea of the materials to be learned, whereas students who apply the surface approach concentrate on surface features of the materials and try to remember them word for word (Heikkilä & Lonka, 2006). Previous research has shown that students’ approaches to learning are related to several characteristics, such as their well-being, study success, and employability (Heikkilä, Lonka, Nieminen, & Niemivirta, 2012; Tuononen, Parpala, & Lindblom, 2017).

For teaching to be sustainable, it is necessary to provide scaffolding for students in the learning environment to support their learning processes. Hattie and Donoghue (2016) proposed that various learning strategies are powerful at certain stages in the learning cycle (see Figure 5). They designed a model based on a synthesis of 228 meta-analyses. The results of these analyses indicate that there is a subset of strategies that are effective, but the effectiveness depends on the phase of learning in which they are implemented. Before highlighting some aspects of this model, it should be noted that educators tend to stress student achievement in terms of grades. However, to educate our students in a sustainable way, educators should focus on learning. In other words, the aim of sustainable teaching is to equip students with learning strategies, or the skills of learning how to learn. According to Hattie and Donoghue, “learning and achievement are not each other’s opposite, they are related.”

The inputs and outputs of Hattie and Donoghue (2016) model are the same: skill (i.e., knowledge and ability), will (i.e., the student’s dispositions that affect learning), and thrill
(i.e., motivations, emotions, and enjoyment of learning). The aim is to help students develop all three. The pre-learning phase is related to whether the students are aware of the criteria of success of the learning task and what it means to be successful at the task/assignment at hand. Students who can articulate the success criteria are more likely to be strategic in their choice of learning strategies. Furthermore, the model highlights the importance of surface and deep learning and does not privilege one over the other. In addition, the model distinguishes between acquiring and consolidating knowledge. During the acquisition phase, information is stored in the short-term memory; during the consolidation phase, a learner needs to actively process the material to increase the likelihood of moving that knowledge to the longer-term memory.

During the phase of surface acquisition, there are many effective strategies, such as organizing and summarizing. At the surface consolidation phase, the investment of effort and deliberate practice is critical. Investment in terms of practice and overlearning is more effective if it is done gradually over time. The strategies related to consolidating learning are heavily dependent on the student's proficiency to invest time on tasks wisely. Deep acquisition is related to the activation of prior knowledge before making relations and extensions beyond what students have learned at the surface phase. During the deep consolidation phase, the power of working with others is most apparent. This involves skills in seeking help from others and listening to others in discussion. Another important strategy is when students become teachers of others and learn from peers, which involves high levels of regulation and monitoring (e.g., sustainable feedback is an important instrument/tool to facilitate deep consolidation).

The model implies an order of the learning phases, but in practice, this is not the case. As Hattie and Donoghue (2018) stated, there can be much overlap in various phases: “to learn subject matter (surface) deeply (i.e., to encode in memory) is helped by exploring and understanding its meaning; success criteria can have a mix of surface and deep, and even demonstrate the transfer to other real-world situations; and often deep learning necessitates returning to acquire specific surface level vocabulary and understanding. In some cases, there can be multiple overlapping processes: learning is iterative and non-linear.” All the distinguished phases are related to effective learning strategies. Hattie and Donoghue’s (2016, 2018) model has received some criticism, however, it provides scaffolding for lecturers whilst designing sustainable learning environments, such as design-based education, and provides challenges for further research.
4.2. Synthesis of elements of sustainable teaching and learning

A sustainable approach to teaching and learning can be visualized by bringing the theoretical insights together: self-regulation, approaches to learning (i.e., intentions and activities), and the six DBE phases (i.e., how to approach “wicked” real-life problems). In Figure 6, these concepts are brought together, representing the multiple layers of a sustainable learning environment.

These layers must be considered whilst designing a learning environment, as they offer a permanent frame of reference that must be confronted to develop a fully balanced, design-based education program. It is important to consider the phases of learning, the associated effective learning strategies, and the intended goals (e.g., self-regulation, metacognition, etc.). Research has shown that alignment in learning environments should be addressed to ultimately reach the intended goals of students (Biggs, 1996).

As stated previously, an important goal of higher education is to support students to exercise control over their own learning and to help them develop skills and learn strategies to take the lead. It should aim to educate students in such a way that they become self-regulative learners, resulting in a lifelong, sustainable impact on their personal and professional development.

To guide the comprehension of and learning about design-based education, a definition of design-based education is formulated. This conceptualization is helpful to design, implement, monitor, evaluate, and adjust design-based education environments.

Design-based education is a teaching and learning approach that empowers the learning process of all stakeholders in (higher) education—a trialogical process between students, the professional field, and lecturers. Actual and complex issues are faced via iterative processes to bridge the gap between a current situation and an intended situation. Characteristics of the non-linear, iterative DBE processes are empathizing, defining, ideating, applying, testing, evaluating, and improving to bridge this gap. The methodological trialogical interaction between students, the professional field, and lecturers is domain-specific. The DBE teaching and learning approach adds value to the education of students, the professional field, and lecturers in terms of gaining multidisciplinary knowledge, developing metacognitive skills, and creating social value.
5. Practical implications

The multiple layers of a sustainable learning environment are helpful when (re)designing or evaluating educational programs. These layers provide a frame of reference, in principles and in guidelines. With this synthesis of theoretical insights into learning, educators can have dialogues about their educational programs. The multi-layered approach gives structure in determining which questions have to be addressed whilst designing and evaluating educational programs. Based on Figure 6, educators must address several questions related to their programs such as: What is aimed for in terms of self-regulation? How can learning activities be organized in such a way that students have to set goals? Are there specific activities directed at reflection? Are educators aware of the importance of acquiring surface knowledge? How can organized learning activities scaffold students to consolidate deep knowledge?

Educators are challenged to apply these theoretical insights to new sustainable learning environments, such as environments that are aligned to the real world. The design of new forms of learning environments, such as workplace education, is challenging. Traditional forms of organizing education is not valid anymore in these (more) authentic learning environments. However, educational scientific insights still need to be addressed. The multiple layers must be addressed while designing or evaluating educational programs, as together they form an integrated approach to sustainable teaching and learning.

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