Chapter 9
Learning Spaces in Context-Aware Educational Networking Technologies in the Digital Age

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Abstract This chapter introduces the concept of learning space in the twenty-first century and considers the various contexts in which learning occurs. The increasing growth of digital educational networking technologies has contributed to the need to create and support various forms of learning spaces. These technologies have also transformed the way students engage and interact off- and online. Contemporary learning, as we know, is no longer limited to physical learning spaces. Instead, students engage in various learning spaces. Others extensively leverage opportunities afforded by social network platforms as tools for collaborative and self-directed learning. Students use social networking technologies to engage with content, connect with peers within their social networks and communicate with their teachers. With the increasing prevalence of these technologies, researchers and educators are provided with new opportunities to extend learning from physical spaces to virtual spaces and optimise pedagogical strategies that can support adaptive learning. Our goal in this chapter is to explore the extent to which understanding of learning spaces and contexts contribute to designing better student engagement and possibly better learning outcomes.

Keywords Learning space · Learning context · Context-aware educational technologies · Educational networking
9.1 Introduction

Many institutions of higher education are exploring innovative learning spaces to support effective engagement of students in their learning. Others have invested in institutional initiatives to redesign the physical presentation of their campuses, implement new technologies and introduce relevant pedagogical modalities.

The development of educational and social networking technologies has led to the emergence of various forms of learning spaces. These technologies have also transformed the way students engage and interact off- and online. Educational institutions continue to provide learning in physical learning spaces primarily. The impact of social networking technologies and other educational enterprise systems (e.g. learning management systems) suggests that learning is no longer limited to physical spaces (e.g. classrooms, libraries and lecture halls). Instead, students are provided with great flexibility in accessing and engaging with various learning resources available in different learning spaces and contexts. They can use repurposed platforms such as social networking ones (e.g. YouTube or Facebook) to collaborate with peers or engage in self-directed learning.

Also, students can by large freely access formal courses offered by other institutions, e.g. massive open online courses (MOOC), or in dedicated environments such as intelligent tutoring systems (ITS). Due to the widespread use of these technologies, students of the twenty-first century can readily engage with content, connect with peers within their social networks and communicate with their teachers.

With the increasing prevalence of social networks and context-aware technologies, researchers and educators are provided with new opportunities to extend the experience of learning from physical spaces to various other types of spaces while optimising pedagogical methods that can support personalisation and adaptive learning. Context-aware technologies are capable of gathering information about the organisation of the learner’s learning space, the content of learning materials
students engage with, the learners’ characteristics (social, cognitive, etc.) and the related educational data on the learning environment. Harvesting these various forms of data provides more valuable insights into the design and optimisation of learning spaces. Research into learning spaces and learning context is critical to the design of context-aware and intelligent environments that are needed for personalisation and adaptive learning.

This chapter examines the concept of learning space in the digital age, its various types and its impact on the context where learning occurs. The chapter also looks at issues related to context modelling in the context-aware educational technologies. The chapter is conceptually grounded and sets the stage for future empirical work in this area. Further, the chapter draws upon work previously carried out in the Technology Enhanced and Teaching in Context (TEEC) (Anjou et al., 2017). The goal, in the long run, is to explore the impact of learning spaces on student’s learning process and learning outcomes, with the ultimate aim of constructing a transformative theory of learning in context.

The chapter is organised as follows: first, we introduce the concept of learning space in the digital age and its impact on the learning process. We begin by examining the literature surrounding the subject. In reviewing the literature, we noticed that, even though the research community acknowledges the value of the learning space in the learning process, there is a dearth of literature on the subject, especially as it relates to learning in the twenty-first century (Sect. 9.2).

Second, we present various dimensions of the concept of learning space, taking into account the contexts in which each dimension can support learning (Sect. 9.3). This leads us to present our ideas about the modelling learning spaces and how it can be implemented to deliver context-aware services (Ejigu, Scuturici, & Brunie, 2007) such as the Context-Aware Intelligent Tutoring System, the CAITS (Forissier et al., 2013).

Third, we argue that learning space and the context in which learning occurs are intertwined (Dey, Abowd, & Salber, 2001). As such, we discuss issues surrounding context and learning space (Sect. 9.4) in order to inform the development of a context-aware learning space framework. This framework supports various educational experiments and improves adaptive and personal learning within the networked educational paradigm.

9.2 Background and Related Research

9.2.1 The Notion of Learning Space

According to Starr-Glass (2018) “learning space denotes a dedicated place (real or virtual), design by the instructor in order to enable students to meet and engage in knowledge creation”. Through a purposeful design of learning spaces, the instructor can help learners to create and personalise learning.
The organisation of learning spaces is often depicted as classrooms with students seating in rows listening and taking notes while a teacher or lecturer stands in front of them and delivers knowledge or information. It is also assumed that learning mainly occurs in classrooms at a fixed time and that it is an individual activity that can be assessed using standard measures. The design of traditional learning spaces is based on the fundamental assumption that learning is mostly confined to formal space (e.g. classrooms or lecture theatres) (Thomas, 2010). Nonetheless, classrooms are not the only environments where students can acquire knowledge since much of learning takes place outside of the classroom (Milne, 2006).

This model of learning space assumes that the student’s progress towards a programme of study is determined by the time spent in classrooms, the physical location of the student in the classroom and their interactions with teachers and other students. As such, the physical design, organisation of the classroom and the seating position of the student in the classroom can affect performance (Xi, Yuan, Yun Qui, & Chiang, 2017). However, the changing landscape of learning environments and students (e.g. diversity in students and learning needs and the permeation of digital technologies into learning) suggests that the traditional notion of the learning space, be it the formal lecture room, the seminar room or tutorial room, is untenable for all types of learning modalities of the twenty-first century.

It is also noted that, in the digital age, educational technologies have shifted from whiteboards to smart boards. This has shifted traditional layouts to open plan and interactive spaces and teacher-led lessons to more collaborative learning experiences.

Moreover, in highly networked learning environments, students interact in multiple modalities during their learning, which is much more complicated than the current portrayal of physical learning spaces as Erstad (2014) stated that the impact of digital technologies since the mid-1990s has implications for where and how learning might happen, whether it is online or offline and situated or distributed. It is also worth noting that while classrooms are formal learning spaces, distributed and networked learning environments can take forms of informal and non-formal learning spaces. Given all these reasons, the old classroom model is becoming archaic for both the student and the teacher.

9.2.2 The Twenty-First Century Student

The twenty-first century learners, the digital natives (Prensky, 2001), are those who grew up with new technologies like social networking ones. They were born from 1982 to the 1990s (Net Generation) and from 1995 to 2010 (Gen Z) (Brown & Lippincott, 2003). They are also known as the Google generation because they master googlism (Jansen, 2010; Biddix, 2011), or the C generation, where C stands for the twenty-first century skills, communication, collaboration, connection and creativity. Their skill in using the Internet and social networking technologies in daily life is similar to those in the educational context (CIBER group, 2008).
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Typically, the characteristics of the twenty-first century students are: social, team-oriented, multitaskers, impulsives, and with short-term attention. They are hands-on with a “let us build it” approach that places increasing value on network devices (Brown & Lippincott, 2003). They do better in active learning, situated learning or learning by doing situation. Their characteristics have spread and are generalising to other generations (Prensky, 2010).

Further, learning for these generations has now become a lifelong pursuit that takes place within technological frontiers that support offline, online and blended learning (Garrison, 2011; Scott, Sorokti, & Merrell, 2016). Moreover, the way they engage with their learning is fundamentally transformed due to the permeation of various educational technologies (Daniel, 2017).

9.3 Learning Spaces in the Digital Age

In the early 2000s, discussions of learning space within many higher educational institutions largely remain constrained to three areas, namely, the classroom (where almost all learning occurs), the library and the faculty offices—where programmes are designed and students’ work are graded (Temple, 2008). In parallel with the fact that the learning space remains mainly physical, institutions of higher education have come to recognise that learning happens in informal, formal and non-formal contexts. Formal learning contexts are those where teachers deliver learning activities within a formally defined curriculum (e.g. degree programme). Examples of formal spaces are a classroom or a technologically enhanced active learning classroom (Brooks, 2012). Selman, Cooke, Selman, and Dampier (1998) describe informal learning spaces as serendipitous and unsystematic (e.g. informal study groups).

In the same vein, Oblinger (2004) describes them as the results of serendipitous interactions among individuals. This type of learning is also referred to as learning outside of “designated class time” (Matthews, Andrews, & Adams, 2011), where learners are likely to acquire and accumulate knowledge skills, attitudes and insights gathered from a lifetime of experiences (Schwier, Morrison, & Daniel, 2009). Non-formal learning environments are organised as systematic educational activities that are often meant as supplementary learning support systems (e.g. learning support centres).

In the late 2000s, the appearance of networked educational and social networking technologies disrupted and transformed the nature of learning spaces leading to the consideration of various contextual factors that affect learning. During more disruptive technological forces, both students and educators owned mobile and ubiquitous technologies such as smartphones and laptops enabling them to access learning on demand, anytime and anywhere. We entered the era of the smartphone as we know it nowadays (e.g. the first iPhone was launched in June 2007).
During the 2010s, a growing body of research has called for the rethinking of learning spaces needed for the twenty-first century (Osborne, 2013; Selwyn, 2012; Temple, 2008). The contemporary forms of active learning involve the use of technologies to engage students with learning materials. The increasing growth in the use of active learning approaches in universities is evident in the transformation of physical learning spaces including the redesign of dynamic layouts that offer mobility and flexibility (Becker et al., 2017; Johnson et al., 2016).

Student-centred learning approaches aim to foster student inquiry, independent learning, collaborative working, active engagement and self-directed learning (Smith, 2017). Moreover, the ability to self-regulate learning requires an understanding of various learning contexts in which learning occurs. This is often shaped by both personal-psychological and contextual factors (Hood, Littlejohn, & Milligan, 2015). It is generally noted that research into learning space provides an opportunity to inform the development of adaptive and personalised technologies to enrich the student individual’s learning need. Beyond that perspective it is possible to open the learning space in order to support the establishment of a social network for exchanges between students across the planet, leading to new educational experiences that might otherwise not be possible to achieve (Stockless, 2018). As Hung and Yuen (2010) noted, social networking technology supplements face-to-face courses and can enhance students’ sense of community.

Our observation of the related literature in the field shows us that, although interesting, the studies carried out so far have focused on an archaic model of the learning space—mainly a physical classroom. Knowing that this model has evolved and continues to do so, it is necessary to consider a more appropriate model of the learning space that encompasses the current practices of the new generation of learners, teachers and instructional designers with educational and social networking technologies.

9.4 Rethinking Learning Spaces: A Conceptual Proposal

Against the above background, we argue that the modelling, the design and the organisation of learning spaces to support learners’ needs in the twenty-first century should take into account the current research evidence on:

- The evolution of spaces where learning happens
- The characteristics of the twenty-first century student
- The use of social networking technologies as educational artefacts

Indeed, although the learning spaces in which learning takes place are still predominantly traditional (classroom, library, etc.), it is time to rethink these spaces in order to take into account the needs of the current generation of learners, the twenty-first century learners, and contribute to their success. Contemporary learning environments, as we know it, transcend physical spaces to virtual, (meta) cognitive and social spaces.
9.4.1 **Physical Learning Spaces**

Physical learning spaces such as lecture theatres, conference halls and retreat venues are valuable learning environments. They are considered part of the holistic view, one of identity and symbolic of power and prestige. However, beyond the classroom, physical learning spaces are quiet spaces or individual pods for individuals or small groups, break out spaces that could be large or small and widened corridors allowing the gathering of students away from the formal learning environments.

9.4.2 **Virtual Learning Spaces**

Virtual learning spaces comprise learning that is mediated both synchronously and asynchronously. In these environments, students learn to multitask and continually work outside of the classroom in spaces that promote social learning. It is viewed as an extension and enhancement of physical spaces. Wilson and Randall (2012) note that this new generation of learning spaces incorporates the use of both physical and virtual spaces.

Most studies on learning spaces have focused on physical space (Brown & Lippincott, 2003; Johnson et al., 2016). In recent years, the use of digital learning technologies alongside physical spaces has enabled synchronous and asynchronous learning activities. Therefore, the need to have different learning spaces in education is increasing, and their incorporation into teaching and learning is becoming more critical. Brown and Lippincott (2003) make it clear that, as the bare minimum, two spaces should be considered critical to learning, those of virtual and physical to integrate them into one environment. Another challenge for learning space design and learning spaces, in general, is the infrastructure necessary for their creation and maintenance. These include funding, faculty training, curriculum development and IT support.

9.4.3 **Cognitive Learning Spaces**

Cognitive learning spaces denote structural characteristics influencing students’ cognitive processes, ranging from visual to acoustic perceptions (Arndt, 2012). Cognitive learning spaces influence learners’ thought processes and learning. Cognitive learning spaces are environments that foster the creation of a specific time for writing or reflection.
9.4.4 Social Learning Spaces

Social network analysis and network visualisations can be used to explore how social interactions between learners can lead to useful learning outcomes. Learning in the context of social networks is highly self-motivated, autonomous and informal, and it forms an integral part of the higher education experience (Dabbagh & Kitsantas, 2012). Also, social networks are considered useful in developing essential skills like selecting relevant information, critically interpreting and analysing the socio-cultural context and working collaboratively and sharing knowledge (Garrison, Anderson, & Archer, 2001). However, the design of the learning space requires incorporation of strategies to create what others have referred to as Social Network Awareness (SNA). SNA is the ability of learners to identify and understand the knowledge context of peers to create a conducive environment for social engagement that is vital for knowledge construction (Lin & Lin, 2019).

Bennett (2007) asserted that “Space designs that acknowledge the social dimension of learning behaviours and that enable students to manage socialising in ways that are positive for learning are likely to encourage more time on task and more productive studying. They thereby yield a better return on the investment in physical learning spaces” (p.18). In the social aspects of learning spaces, the concepts of learning ecology (Scott et al., 2016) and learning communities (Schwier et al., 2009) are critical because they emphasise learning in a social context while recognising that learners are simultaneously involved in multiple learning settings. The social learning spaces that are capable of the blending of formal and informal learning are likely to facilitate situated and personalised learning experiences (Kovanović, Joksimović, Gašević, & Siemens, 2017). Furthermore, Oblinger (2005) pointed out that “learning is an active, collaborative, and social process that hinges on people” and that an ideal learning space is one that encourages engagement of various modalities with student peers as well as teachers.

A learning ecology is a collection of contexts—physical and virtual—that provides opportunities for learning (Scott et al., 2016). In higher education, this usually includes learning that takes place in formal, informal and non-formal contexts. Such an array of learning can take place across the institution, work settings, community and at home. Social learning spaces are instrumental in setting conditions for learning because they create a supportive environment to engage students in critical thinking and promote interactions that are richer, more gratifying and intrinsically rewarding (Garrison et al., 2001; Matthews et al., 2011).

We take the above holistic view of learning space, rethinking it along those four key dimensions (Fig. 9.1) in order to support the twenty-first century students with relevant educational networking technologies.
9.5 Weaving Learning Space with Context Awareness

9.5.1 The Notion of Context

In artificial intelligence, the notion of context appeared in the 1990s (McCarthy, 1993), but it was not until the early 2000s where this area of research gained interests among researchers in ubiquitous and pervasive computing, mainly focusing on geolocation technologies, where the spatial and temporal dimension of the context became traceable.

Dey et al. (2001), in their definition, which is still the most widely accepted definition of the context, stated that “context as any information that can be used to characterize the situation of an entity, where an entity is a person, place or object that is considered relevant to the interaction between a user and an application”.

Bazire and Brézillon (2005) have analysed 150 definitions of the context. From this study results the most cited model of context among research. It represents the components of a situation and the relations between them. According to Bazire and Brézillon (2005), “A situation could be defined by a user, an item in a particular environment, and eventually an observer”. In their model of context, context and environment are separate but related.

Since 2007, CONTEXT symposia have opened the study of this concept to education where space takes a central place. Thus, according to Bettini et al. (2010),
“space is an important context in many context-aware applications, and most context definitions mention space as a vital factor”.

According to Miraoui (2018), context is the set of circumstances or facts that surround a particular event or situation. In education, the concept describes the various and possible circumstances in which learning might occur.

The learning context consists of students, cultural aspect, teachers, lesson plans, etc. Learning space refers to an episodic and specific moment where learning occurs. Learning context describes various aspects of the learning spaces and the relationship between them. It also refers to students’ perceptions of a particular space in optimising an enriched learning experience accrued from a particular learning space.

Learning context can also be regarded as the set of learning activities and expected learning outcomes, including the space in which learning itself occurs. Context and space work together, whereby context facilitates the process of learning while learning space helps achieve it. For instance, Brézillon (2011) indicated that in physical learning space, participants use a large part of contextual information to translate, interpret and understand the utterances of others by using contextual cues like mimics, voice modulation and movement of a hand. Brezillon stresses that the efficacy of an expert system is dependent on the acquisition of knowledge of the problem being solved, the proposed solution, the situated context in which the problem prevails and the extension of the solution.

Learning context is critical to the determination of learning outcomes. It provides us with an understanding of the current context of the learner, their state of knowledge, their learning trajectories within the learning space, the relevant and suitable learning materials needed for them to succeed and the moments and space in which they learn best.

9.5.2 The Concept of Context in Education

The notion of context in education describes the various circumstances in which learning might occur, where the learning context consists of students, culture, teachers, lesson plans, etc. Context can also be regarded as the set of learning activities, expected learning outcomes, including the space in which learning itself occurs.

Context enables both teachers and students to rethink about the design of teaching and learning and the constraints of the learning spaces (Alterator & Deed, 2013). The affordances of a context must be perceived by an individual who must also have the abilities to interact with these attributes. Although openness can disrupt teaching conventions, it is the social activity of the inhabitants that define the possibilities of learning space (Lefebvre, 1991).

The emergence of massive open online courses (MOOC) in 2008 and the subsequent possibility of accessing extensive data about student interactions in online learning situations triggered more interests in understanding context and learning.
Recently, studies have emerged on didactic contextualisation (symposium on didactic contextualisation, 2011), in teaching in context (Forissier et al., 2013; Psyché et al., 2018). Bourdeau et al. (2015) stressed the importance of the external context in networked collaborative learning. According to these authors, the external context of a learning situation is influenced by environmental factors that have subsequent impacts on the learning process (Anjou et al., 2017). They used this hypothesis to guide the development of context-aware tools inside a Technology Enhanced Teaching in Context (TEEC) project. Among them, a calculator that computes the nature of context (MazCalc), some context-aware authoring services and a context-aware intelligent system (CAITS) are envisioned.

The TEEC project sought to create models of context and context-aware tools for students to discover the importance of context when learning in domains such as biology, geology, French, sustainable development, and social economics. The research was motivated by the observation that science learning tends to happen in various contexts (Bourdeau, 2017) and that significance of context in intelligent tutoring systems (ITS) was not fully understood since ITS concentrated on modelling the domain, the learner and the tutoring (Woolf, 2010). The TEEC project introduced the significance of context and its role in science learning by encouraging learners to explore and discover moments of learning within a particular context, likely to lead to conceptual understanding.

9.6 Research Motivation

In the present study, we explore the concept of learning space in the digital age and its impact on the learning process.

We know that research has associated the design and organisation of learning spaces for course design with student achievement, mastery and retention (Oblinger, 2005; Ramsay, Guo, & Pursel, 2017). Moreover, recently, research has been extended to explore the impact of learning spaces on student learning outcomes (Griffith, Vercellotti, & Folkers, 2019). Also, research on interactive learning space classrooms has reported that instructors and students find them engaging, and engagement is expected to increase learning outcomes (Vercellotti, 2018). We hypothesise that the design and organisation of learning spaces in the digital age have the same positive impact on the learning process than the traditional learning spaces. However, until now, researches have focused mainly on physical or hybrid learning spaces. Our research focuses on various other forms of learning spaces.

Based on the above, we have set up some broad research directions relating to:

1. Measuring the impact of our research on a student learning: measuring the impact of learning space on a student learning.
2. Developing models, tools and services derived from research results: learning space context-aware models (e.g. ontologies), tools (e.g. a CAITS, a Context-Aware Intelligent Tutoring System, etc.) and services (e.g. context-aware authoring services) for optimal student learning.
9.7 Pilot Study

9.7.1 The TEEC Project as a Test Bed for Experimenting Learning Spaces

In this section, we introduce the TEEC\(^1\) (Technology Enhanced and tEaching in Context) project as a test bed for implementing learning spaces. The development of the project provides a pedagogical structure and a technological environment for specifying, implementing and testing the concept of learning space for Collaborative Distance Learning (CDL) using network technologies. Subsections are project description, Learning scenario, context-aware system architecture proposal and the design-based research (DBR) methodology. The TEEC pedagogical structure and its technological environment are considered a valuable hypothesis for deploying the ideas of learning spaces exposed above in this chapter.

9.7.2 Project Description

The TEEC project is an international project aiming at providing the foundations as well as the experimentation of context-aware systems to support collaborative learning at a distance using network technologies. The foundations are the following: Given an object of study, conceptual change can occur if the clash between two learning contexts is strong, highlighted and socially mediated. This model is called the CLASH. Moreover, in order to provide a scientific foundation for context selection, the MazCalc context gap calculator has been developed (Anjou et al., 2017). The model allows the specification of parameters and values, and the computation of the gap between two contexts, both global and parameter-specific. Should the result be too low, the learning design can be modified accordingly to obtain a more significant learning design using the DBR methodology. Similar projects are promoted among others in Europe through its etwinning initiative (https://www.etwinning.net/en/pub/about.htm).

The TEEC team experimented with only two contexts since adding a third one adds more complexity. The team conducted design experiments with various domains and topics as well as various educational levels. Domains and topics include biology, geology, environmental science, social science and history and language science. Educational levels go from primary education to university education. Plus, the experimentations were conducted among partners using the same language (French), despite apparent but productive disparities. Future work should extend these foundations to partners not sharing the same language, which again means adding another level of complexity.

\(^1\)https://teec.teluq.ca/en/
9.7.3 Learning Scenario

A learning scenario in the TEEC project using the MazCalc contains the following steps:

- Establish a potential collaboration between partners in a domain and at a specific educational level while considering existing curricula, teaching and evaluation practices and technologies available on both sides. Inquiry learning is recommended with learners who have to conduct some field-based research, collect data and analyse them under the guidance of the teacher.
- Select an object of study (topic) with sufficient potential in contrast of contexts as well as the feasibility of a field study on both sides.
- Select themes (subtopics) relevant to the topic and the contexts as well as the feasibility of a field study on both sides.
- Identify parameters and their potential values for calculating the context with MazCalc.
- Enter the parameters and the values into the MazCalc software, and get the results to adjust the selection of the object of study and its context parameters to obtain an accurate prediction of productive learning through “a clash of contexts” and a conceptual change.
- Design the learning scenario according to instructional design principles following the ADDIE (Analysis-Design-Development-Implementation-Evaluation) methodology: specify actors, activities, resources, time and space.
- Actor means a set of roles that can be played by a person or another (students can have the role of teaching other students). Teaching and learning activities are selected based on their relevance to support learning (inquiry learning where learners conduct field-based research, collect data and analyse them under the guidance of teachers).

Time and space indicate the synchronous versus asynchronous communication activities and the field-based versus the classroom or lab activities. The two learning scenarios that inspire the TEEC basic scenario are Aronson’s Jigsaw scenario (Aronson et al., 1978) and Schwartz’s LEGACY inquiry cycle (Schwartz, Lin, Brophy, & Bransford, 1999). As a result, the pattern for a TEEC learning scenario comprises five main components, as illustrated in Fig. 9.2.

9.7.4 The Case of Geothermal

The case of geothermal is the best-documented experimentation of the TEEC project so far, as described by Anjou et al. (2017, in English) and Anjou (2018, in French) in her PhD dissertation. It has experimented at two levels: university level with future science teachers and primary school level.

The following disparities produce the contrast of contexts: Geothermy in Guadeloupe means the production of electricity powered by high-temperature water...
from deep layers in a recently formed geological structure in the Caribbean area. In Quebec, it means drilling rocks at a shallow level in the world’s oldest geological structure to get a low-temperature increase for warming individual homes with a heat pump. Results of these two experiments indicate that the combination of the CLASH model and various contexts that involved the jigsaw inquiry learning scenario, where learners engage in the inquiry process, was productive, particularly achieving the objectives of the study (geothermal).

9.8 The Context-Aware System Architecture Proposal

The context-aware system architecture in the TEEC project includes an intelligent tutoring system. We called it the Context-Aware Intelligent Tutoring System (CAITS) architecture. It is original in that it incorporates two more models into the traditional ITS architecture: Contexts and Computer-Supported Collaborative Learning (CSCL) (Fig. 9.3).

According to Woolf (2010), an underlying ITS architecture is composed of four components: a domain model, a learner model, an instructional model and a user interface model.

Model; CSTM, context-sensitive tutoring model; CSLM, context-sensitive learner model; CSLS, context-sensitive learning scenario; Database CEM, Context Effect Manager Board (MazCalc Query interface + Parameter Visualization screen board + Calibration Tools.)
VanLehn recently suggested adding CSCL to this architecture (VanLehn, 2016) and to configure the step and task loops according to its requirements. However, it is not clear how a learner could interact with her learning space while performing activities alternatively as an individual, a team or a group member.

As early as 2011, Isotani et al. underlined the need for taking CSCL into account in an ITS architecture. In their systematic review of Authoring Tools for Designing Intelligent Tutoring Systems, Beemer, Spoon, He, Fan, and Levine (2018) suggested that the next generation of ITS Authoring Systems incorporates collaborative learning. Sottilare et al. (2018) proposed an authoring framework for Designing Adaptive Instruction for Teams, and Fletcher et al. (2018) proposed a Shared Mental Models in Support of Adaptive Instruction for Teams Using the GIFT Tutoring Architecture. However, none of them takes into account the context in which teams can live and how different or even contrasted it can be.

The TEEC architecture not only provides a context model for each team but also calculates the contrast between two contexts for the same object of study, predicts the productive effect for learning on both sides and governs the instructional scenario with its actors, activities and resources.

9.9 Methods

9.9.1 What Is Design-Based Research?

The design-based research methodology (thereafter called DBR) has its roots in the pioneering work by Brown (Alterator & Deed, 2013) under the name of design experiments, in an effort to reduce the gap between lab research and in situ research
and to allow a process by which both theory and practice can evolve together, based on a design process. It relies upon a cybernetic principle where the result of each loop changes the behaviour of a system. DBR then evolved into a full methodology which was claimed by the DBR Research Collective and published in the *Educational Researcher Journal* (Anjou et al., 2017,) sustained by an article in the *Journal of the Learning Sciences* (Arndt, 2012), another one by Wang and Hannafin entitled design-based research and technology-enhanced learning environments (Bazire & Brézillon, 2005) and another one by Herrington et al. It has been applied in numerous pedagogical innovations (Bazire & Brézillon, 2005; Bennett, 2007; Bettini et al., 2010; Bourdeau, 2017; Branch, 2009; Brézillon, 2011). DBR can be characterised as a microsystemic methodology, based on system science principles, mainly the feedback loops mechanisms, or iterations, and the goal of comprising the complexity of an authentic situation to study it.

In contrast to experimental research, it does not aim to isolate nor control. Unlike participatory design, it promotes the development of theoretical knowledge simultaneously to the design of artefacts. To our knowledge, DBR has not been applied to study the design of collaborative learning, nor the design of context-aware learning environments nor to Learning Spaces.

In the TEEC project, in order to achieve our objectives and test the hypotheses, while working on many fronts at the same time, we needed a methodology that would: (1) allow us to tackle the design of several components at the same time, (2) be concerned both with theory and practice, (3) account for the complexity of the learning situation, (4) respect the authenticity of the learning tasks, (5) allow us to produce results repeatedly along the development of the project, (6) allow us to test not only the hypotheses but also the components. The DBR methodology proved to be the best candidate for our project, even though it had not been applied yet to the study of context in learning, nor to telecollaborative learning, nor the design of a context-aware learning environment (Bourdeau, 2017).

The generic DBR process was instantiated in the following way: four components and three feedback loops for each iteration (see Fig. 9.4). The four components are: context modelling, instructional scenario, experimentation with data collection and results and lessons learned. An iteration means using the methodology for a specific domain and a specific learning situation, such as biology with primary school learners.

### 9.10 Linkages between Learning Space and Context

In order to investigate the linkage between learning space and context, we will adopt a methodology which takes into account knowledge engineering, instructional design models and design-based research, among others. The methodology would involve the conception and modelling of the context model of different learning spaces (see Fig. 9.5). The model draws from Bazire and Brézillon (2005), which considers various forms of the environment (physical, virtual, social and cognitive).
In this model we take into account the “spatiotemporal location” component of the context, where the “items” represents any learning systems (e.g. in intelligent tutoring, computer-supported collaborative learning systems or massive open online courses).

The second phase of the methodology will involve the construction of an ontology of learning spaces. This ontology will be built from a reflexion on the relationship between learning space and learning situation (see Table 9.1). The ontology...
will inform the development of use case scenarios demonstrating various forms of learning spaces.

The third phase of the methodology would involve running user experiments, where learners will be engaged in learning activities, and their overall learning experiences will be evaluated, taking into account the possible factors they attribute to enhanced learning outcomes or experience and space and the context in which this occurs.

The design of the learning activities will be informed by an instructional design model which involves analysis, design, development, implementation and evaluation (ADDIE) (Branch, 2009). This model fits the construction of a performance-based learning scenario. According to Branch, the ADDIE model provides a way to address the complexities associated with learning spaces (Branch, 2009). Using ADDIE will design learning scenarios based on two or more different learning contexts for students and evaluate students’ learning experiences in each context. We will also collect learning analytics, learners’ profiles to build a knowledge base (activity trace templates). The analysis of the knowledge base will help validate the ontology of the learning spaces and the discovery of contextual knowledge.

9.11 Discussion

Research shows that the current design of learning spaces in higher education is no longer adequate for innovative pedagogies that take the twenty-first century student learning needs into account (Ramsay et al., 2017). Learning happens in various contexts and different learning spaces. Research relating to the various contexts where learning takes place has become much more critical than before due to the increasing deployment of digital and networking technologies and diverse needs and expectations of students relating to how they access learning resources. For instance, it is critical to the design of context-aware instructional scenario
embedded in learning environments (e.g. intelligent tutoring or computer-supported collaborative learning systems or massive open online courses) to provide personalised individual or collaborative learning pathways (Chou, Lai, Chao, Lan, & Chen, 2015; Lavoué, Molinari, Prié, & Khezami, 2015; Van Leeuwen, Janssen, Erkens, & Brekelmans, 2014).

To attract and retain modern students, as well as improve engagement and drive better learning outcomes, institutions of higher education need to explore various contexts and spaces in which students learn, as well as leveraging pedagogical innovations that support blended, virtual and social learning.

The deployment of various educational networked technologies in different learning spaces generates rich data about students and their learning pathways. The growing number of computational and analytical tools that can capture students’ interactions (when, what, where and how) provide numerous opportunities to harness such data and optimise learning spaces. Such data can be used to provide students with more accurate and faster feedback (Mayer-Schönberger & Cukier, 2014).

Similarly, teachers can use data obtained from students to reflect on their pedagogical design and optimise the learning environment to meet students’ diverse needs and expectations. While the ability to track, harvest and analyse various forms of analytics (social, cognitive, affective and education) can reveal useful insights about learners in interaction with learning environments, methodologies to combine data from learning spaces with data from learner’s interaction are lacking (Daniel, 2019; Hood et al., 2015; Hong, Scardamalia, Messina, & Teo, 2015; Kickmeier-Rust & Firtova, 2018). Consequently, there are limited learning context models which include the learning space context.

Also, there are limited instructional design methodologies or instructional models and scenarios which take into account the learning space context. “The organisation of learning space, whether physical or virtual, can have an impact on learning” (Oblinger & Lippincott, 2006). In recent times, learning has become an activity that can occur anywhere and so the idea, that is, learning only happens in physical spaces. In other words, the idea that the students sit and listen to a lecturer for a certain amount of time and then leave is by significance a myth. The transmission form of learning often sustained through physical spaces is becoming an unsustainable model. It does not meet the diverse needs of students and contradicts active learning, an idea that promotes participation and experiential learning.

The constructivist learning approach favours learning that is contextual, active, and social. It may also foster collaboration. In the twenty-first century, learners are highly social and prefer learning spaces that are highly distributed, adaptive and personalised. This is an indication of the importance of the design of learning spaces as they can determine how learning occurs (Temple, 2008).

Universities have made growing investments in redesigning physical learning spaces and equipping them with new digital technologies. These technologies help enhance the physical learning space by providing more diverse activities and influencing the organisation of pedagogy and student learning. Digital learning technologies support active learning activities such as lecture capture, class discussion and provisions of digital lectures (Daniel and Bird in press).
The combination of digital learning technologies and new forms of pedagogy can support social learning spaces. Educators have the opportunity to integrate these new spaces into their students learning environments in order to widen their students’ horizons in terms of constructing knowledge. Besides the social learning space, virtual learning spaces provide highly interactive synchronous and asynchronous social networks that are useful for supporting knowledge acquisition.

The nature of these virtual spaces offers the twenty-first century students the ability to be mobile and the capability to multitask. These are some of the traits that are common in current students. The idea of learning spaces, therefore, helps educators envision the various places in which learning can occur. Moreover, it should help them design learning environments that factor in the notion that learning can occur anywhere anytime.

The design of useful learning space requires consideration of the learning content and the activities required for learning. Muñoz-Cristóbal, Gallego-Lema, Arribas-Cubero, Martínez-Monés, and Asensio-Pérez (2017) presented the idea of a learning bucket in virtual learning communities. A learning bucket is a conceptual proposal to help teachers orchestrate learning situations that involve multiple physical and virtual spaces (Muñoz-Cristóbal et al., 2013). A learning bucket is a configurable container of learning artefacts of multiple types (e.g. 3D models, web pages, artefacts generated with Web 2.0 tools such as Google Docs documents, etc.). The concept of learning bucket aims to introduce flexibility in learning spaces where teachers experiment with various forms of modalities (Muñoz-Cristóbal et al., 2015). With learning buckets, teachers make strategic choices in the design of learning activities and artefacts and choose appropriate pedagogies to support effective learning.

9.12 Conclusion and Open Questions

Learning space refers to an episodic and specific moment where learning occurs. Digital learning technologies have transformed the way students engage and interact off- and online, yet the physical learning spaces in which learning occurs have not changed much. In this chapter, we introduced the concept of learning space in the digital age and the various contexts in which learning occurs. We situated our discussion of learning space about the design of learning space context-aware ontologies, learning scenarios and tools. We aim to construct a transformative theory of context-aware learning spaces such as personal learning networks, virtual learning spaces, social learning spaces and cognitive learning spaces. The current learning environment has been primarily restricted to the classroom or lecture theatre. Classrooms are learning spaces usually portrayed as students seating in rows and intently listening and taking notes while a teacher or lecturer is standing in front of them delivering knowledge or information. This model of learning environment purports that students’ progress towards a degree is determined by the time
spent in classrooms and interactions with teachers and other students. However, the model of learning was disrupted in the late 1990s when distributed, and online educational technologies drastically transformed space, time, context and the nature of learning. Critiques of the traditional learning spaces have since emerged. Many of them mainly argue against common learning spaces (classrooms) because they find them inefficient. Institutions of higher education recognise that learning happens in a variety of contexts including informal, formal, non-formal and online.

Although the literature has mostly focused on redesigning physical spaces (Brown & Lippincott, 2003; Johnson et al., 2016), it is essential to look at other dimensions of learning spaces such as social, cognitive, and virtual. We argue that understanding the various forms of learning spaces enable us to better redesign learning spaces to cater for all forms of learning, pedagogues, and students. Further, the design of learning spaces should be in conjunction with the entire institution so as to make them worthwhile and more applicable to their intended audience while providing for the right support that can maintain the design of the learning space since technology learning spaces and support services are mutually dependent (Brown & Lippincott, 2003). We are aware that providing support to all forms of learning spaces cannot necessarily enable students to transition from one space to another without facing any challenges. It is essential to be aware that students tend to spend more time in informal learning environments rather than formal learning environments (Johnson et al. 2016).

In this chapter, we exposed the foundations for learning spaces and for applying them to context-aware systems for educational networking. We identified several questions that remain open and require further work, among them:

• What are the limits of a personal learning space?
• Can we design it to adapt to collaborative and social learning activities, and what would be the requirements for this development?
• Since CSCL is declined after several levels (individual, interindividual, team, intrateam, interteams, intragroup, intergroup), how can we envisage these multiple dimensions, both conceptually and in terms of implementation?
• Automatic detection and adaptation, the launching of appropriate applications, are significant challenges as well as coping with the learner model and the learner analytics associated. How would this be approached?
• How possible and feasible is it to add more levels of complexity than in the TEEC project, such as having three or more contexts, or different languages?
• How can learning analytics inform and improve the learning design of context-based activities using the DBR methodology?

Our future work involves the modelling of context-aware ontologies and conducting a series of experiments to construct a transformative learning theory that takes into account the various contexts of learning spaces (physical, virtual, social, cognitive and metacognitive).
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