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An ecological perspective on learner-constructed learning spaces

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Abstract

This paper argues for the need to develop a relational, emergent and plural understanding of learning spaces. We take an ecological perspective on learning, which allows us to conceptualize learning spaces as (co-)constructed by learners; emerging through learners' practices, interactions and activities; and facilitated by pedagogical arrangements. In the co-construction of spaces for learning, tapping into various ecologies of resources—whether intellectual, relational or digital material—becomes an organic, iterative, agentic endeavour for learners. This paper proposes a set of principles to synthesize this conceptualization and facilitates an understanding of such emergent learning spaces. An empirical illustration extracted from a collaborative student project in software engineering education contributes to grounding the conceptual argument and provides a clarifying example. Ultimately, this contribution suggests that in order to support the emergence of learning spaces that are resource-rich and conducive to learning, educational contexts and pedagogical arrangements must provide both the framing conditions and also the flexibility and permeability required to access the wider ecologies of resources made available through digital technologies.

Introduction

In its present heyday, the educational landscape of the digital age is undergoing a surfeit of unforeseen changes. These changes, broadly subsumed under the categories of rapid knowledge transmission, vast knowledge accumulation, and choice proliferation of digital technologies (Castañeda & Selwyn, 2018), challenge deep-seated assumptions about learning and trigger the need to rethink how we conceptualize learning, teaching and design practices. According to several scholarly reports, these emergent practices transcend traditional modes of learning (Eberle, Lund, Tchounikine, & Fischer, 2016; Leander, Phillips, & Taylor, 2010) and draw on distributed sets of resources, actors, and forms of knowledge along with unceasing interaction amongst people, technologies, resources and spaces of various types (Akkerman & Bakker, 2018; Fischer,

Practitioner Notes

What is already known about this topic

- Learning spaces can be individual or collective.
- Physical space is an important element that can facilitate or hinder learning.
- Technology can contribute to hosting learning spaces (eg, online).

What this paper adds

- A potential new conceptualization drawing on an ecological perspective on learning.
- Insights into how learning spaces are customized versions of the learners' intellectual, relational or digital-material resources available in various contexts.
- Examples of how learning spaces are constitutive through learners' individual or collective practices, based on affordances provided by pedagogical designs.
- Propositions on how pedagogical designs can provide learners with opportunities to access wider ecologies of resources made available through digital technologies.

Implications for practice and/or policy

- Teachers need support to develop pedagogical designs that support learners in creating their own learning spaces.
- Helping students to create their learning spaces requires guidance, which must be facilitated by appropriate institutional infrastructures and conditions.
- Professional learning approaches are needed to build teachers' knowledge and capacities to support students.
- Institutional arrangements must be open to change.

Hmelo-Silver, Goldman, & Reimann, 2018). The spaces in which learning is organized and takes place have inevitably changed in nature, becoming increasingly permeable and dynamic.

The task of understanding how such learning spaces emerge and can be facilitated is formidable and currently escapes scholarly consensus. As a baseline for this endeavour, learning research provides a vast repertoire of accounts of processes of embodied or situated cognition, cognitive understanding interwoven with social or relational dimensions or digital material contexts shaping new experiential connections that are constitutive to learning. In particular, with reference to learning in digital contexts, there has been long-standing interest in pedagogical and technological means that are supposed to transcend institutional, disciplinary, social and cultural boundaries and can enable extended learning spaces that are less time–space–place bound. Examples are personal learning environments (eg, Wilson *et al.*, 2006), community-based learning environments (eg, Scardamalia & Bereiter, 2006), or massive open online courses (eg, Jeong, Cress, Moskaliuk, & Kimmerle, 2017). This line of inquiry allows thinkers to respond to the community's pressing concerns about the relevance and expediency of knowledge, the role of pedagogical structures and teacher support and the role of digital technology as a tool that can facilitate learning. However, this class of interpretations does not necessarily account for disruptive, emergent practices or address ways of thinking about how learning bestows meaning. These efforts towards the development of tailorable learning environments still frequently draw on an instrumental understanding of technology and pay little attention to the *enacted* processes through which learning spaces are (co-)constructed (in activity), used and maintained *by learners* (see also Goodyear & Dimitriadis, 2013; Kali, McKenney, & Sagy, 2015). Therefore, the task of reflecting on how learning spaces are configured in situ is left outside the scope and analytical intentions of the former side of the debate.

This paper's goal

One of the principal merits of the literature on learning spaces is the invitation for critical reflection regarding its own working vocabulary. Several scholars in this field of research have emphasized the frequent confusion between spaces, places and environments (Ellis & Goodyear, 2016; Hod, 2017), with the main point of criticism being the vagueness and interchangeable use of the special connotation of digital technology as a mediator of learning processes. These critical remarks provide the initial baseline for our argument. Namely, the function of teaching learning design and digital technologies is primarily to support people in configuring their own learning spaces, becoming more self-sufficient in navigating and (re-)assembling ecologies of resources and developing the competences needed to be autonomous, lifelong learners. In line with Goodyear, Ellis, and Marmot (2018), we maintain that facilitating the sustained construction of such learning spaces is not primarily concerned with "optimizing an environment for a proximal educational goal" (p. 232), but rather, with supporting learners in organizing complexity and sense-making in unbound landscapes where intellectual, relational, material or digital resources exist in abundance. In our inquiry, we make a distinction between learning spaces and learning environments as defined in the mainstream learning research literature (see Damşa & de Lange, 2019), which are set or designed by the teacher with an (indirect) educational purpose.

To that end, this paper explores the relevance of an ecological perspective with regard to learning and learning spaces. We view this perspective as instrumental in the attempt to capture the cross-spatiality invoked in the arguments of learning being/constituting an expansive process that exceeds contexts, boundaries or physical constraints, with increased connectivity made possible by digital technologies yet achieved by the learners themselves. The question we raise is what it means for the understanding of learning spaces when, instead of taking a departure point in the normative requirements learners are expected to meet, we build a conceptualization wherein the *enacted* processes by which individuals develop their capabilities as learners are central. Rather than judging how well learners adjust to a fixed set of outcomes and expectations (eg, exam standards or fixed curriculum structures), the concern should be about (1) how spaces for learning are being shaped (or constructed) in a way that capitalizes on resources in the academic environment (and other environments offering learning opportunities) and (2) how these spaces are conducive to learning and enable learners to act, engage, interact or perform.

In the rest of this paper, we first articulate what an ecological perspective on learning entails. Second, we elaborate on a reconceptualization of learning spaces viewed through an ecological lens and propose a set of generic principles that synthesize this conceptualization. An example from a software engineering course illustrates the emergent nature of a student group's learning space, which is expanded by using digital media and resources beyond the established learning space set by the institutional framing. Third, we display the ramifications of the ecological perspective for facilitating the emergence of learning spaces and discuss implications for further research and practice.

An ecological perspective on learning

With reference to learning, the ecology metaphor (cf. Barron, 2006; Brown, 2000; Damşa & Jornet, 2016) is inspired by the study of the relationships of organisms with one another and their environment (Bateson, 1972; Bronfenbrenner, 1979; Dewey & Bentley, 1949/1999; Gibson, 1979). It builds on the dialectic premises that underlie sociocultural, situative and sociomaterial approaches, but emphasizes a core premise that is strongly at variance with ideas that still dominate mainstream perspectives on learning: namely, that learning is not a confined, internal process but instead involves mutually constitutive relationships between individuals and their (social, intellectual and digital material) environments, where both person and environment are

transformed. According to a sociocultural line of reasoning, the individual actively relates to environments of various natures (social, economic, cultural, personal, institutional) and those relationships then become internalized to form part of how a person knows and develops (Vygotsky, 1987). But the individual also initiates externalization, production of knowledge or production of materials and, through this process, acts upon and changes the world. This understanding indicates both the way that knowledge, relationships and materials are organized, but also how they can be drawn upon by learners who are engaged in their own process of sense-making and learning. Furthermore, learners may approach a variety of distributed resources and relate to different actions and environments (eg, professional, social, cultural, digital). The way we view it, an *ecology of resources* contains the wider pools of resources and infrastructures that learners can draw upon to construct their own learning spaces.

Learning spaces viewed from an ecological perspective

How is this perspective relevant to understanding future learning spaces? *First*, in traditional learning paradigms, knowledge of the domains is validated and "translated" into curricula adhering to given rules and structures. The current perspective assumes that learners themselves *co-construct* knowledge and practices, meaning they "negotiate" meanings about given knowledge or practices, and it denotes processes where the focus is on collective participation and transformative experiences (Damşa & Jornet, 2016). *Second*, an ecological perspective views materials as constituting meaning-making resources, with the materials and people's thinking and doing being inextricably intertwined through the processes of meaning-making (Säljö, 2010). The things of learning, or "learning activities and spaces, knowledge representations such as texts, pedagogy, curriculum content, and so forth" (Fenwick, Edwards, & Sawchuk, 2011, p. 2), cannot be taken for granted but are seen as "themselves effects of heterogeneous relations" (p. 2). Rather, learners orient towards materials which organize their perceptions and actions and, in turn, act and come to transform the very materials that shaped their own meaning-making in the first place. *Finally*, the mutuality of these constitutive relations is important for how people move across physical and digital contexts to access and share information. An ecological perspective fills the need for an account that adequately describes the intellectual, social and relational trajectories involved in moving across such contexts' boundaries (Akkerman & Bakker, 2018). Navigating these settings and assembling resources through which individual or collective intellectual goals, needs and development are addressed by capitalizing on domain knowledge, instruction, resources and/or infrastructure becomes key (see Damşa & de Lange, 2019; Markauskaite & Goodyear, 2017; Yeoman & Ashmore, 2018). This implies an analytical view of learning as not only a shared and collective process but also as distributed across contexts and materials.

An ecological perspective on learning allows for consideration of how learning spaces can emerge through the interactions of learners, resources and (digital) tools. This may require the learners to move back and forth between physical and virtual contexts, facilitated by learning designs, digital technologies and appropriate guidance that together promote ways of engaging with novel ideas, knowledge, people or other available resources. This outlined conceptualization is synthesized into a set of underlying principles highlighting how learning spaces are enacted by learners. We, therefore, propose the following principles:

A. Learning spaces are principally immaterial in nature and are spaces of action, where learners' goals, knowledge, doing and making emerge.
B. Learning spaces can, in part, be preconfigured by teachers but are (re/co-)constructed by the learners when enacted. Therefore, learners' agency (and skill) is of crucial importance because learners sustain this process.

C. Learning spaces are relational in nature, which implies that the learner relates and engages with resources, for example, knowledge, people, materials, digital, from local or extended (beyond school) contexts.
D. The educational context, with its institutional, material or digital infrastructure and pedagogical arrangements (eg, learning design, teacher support) facilitate frameworks and ecologies of resources that provide scaffolding for learning spaces.

Ecologies of resources and spaces of action

Principles A and C connect the evolving conceptualization of learning spaces to the notion of *ecology of resources*, described as "a set of inter-related resource elements, including people and objects, the interactions between which provide a particular context" (Luckin, 2008, p. 4). The dynamics of the knowledge domains and abundance of virtually available resources require learners to regularly navigate complex, knowledge-laden environments and engage with rich and varied sets of resources. In such contexts, learning involves efforts to "assemble a learning space" (Markauskaite & Goodyear, 2017) in which individual or collective learning goals and needs are addressed by capitalizing on domain-specific conceptual or practical knowledge, others' expertise, or other digital material resources. Learning spaces in their standard manifestation seek to foster a closer connection between the different learning activities and, simultaneously, between different learning communities (Ellis & Goodyear, 2016; Hod, 2017; Rook, Choi, & McDonald, 2015). Future learning spaces, as a line of scholarship, call for renegotiating the established learning practices by drawing attention to evidence-based practices and the rich potential of the synergy between active group/community members, networked practices of enquiry (Ellis & Goodyear, 2016; Hod, 2017) and hybrid ecologies of resources (Damşa & Jornet, 2016). Furthermore, this offers a useful critical foil for outlining a sophisticated account that comes to grips with the unforeseen and the unique learner's ecology of resources in refashioning a learning space. Simply put, an ecological perspective casts light on the process and the fertile descriptive reality *of the learner* by illustrating how digital resources can promulgate a learning space that will be iterative and organic rather than systematic and predictable.

Co-construction and agency

As suggested by Principle B, the premises of an ecological perspective essentially assign the learners the prerogative—as well as the responsibility—of shaping/creating and managing their learning spaces. This emerges from the underlying idea that construction (of meaning, knowledge, practices, etc.) is an active process; to paraphrase Dewey and Bentley (1949/1999), the learner is an actor who, through active participation, affects the process itself and the knowledge obtained. This process can be carried out in or by groups and communities in addition to individuals, and then goal-oriented individuals act meaningfully and interactively with input from the others. The goal orientation directs these processes and funnels the active role attributed to the person who is appropriating the world. This is not a trivial endeavour, as we envision the process of drawing upon the vast and varied ecologies of resources as being emergent, meaning that learners do not always have a predefined intention and strategy in doing so, nor do they have a strategy for when to do it or in what way. At this level, the agency of learners, whether individual or collective, is a crucial aspect because it has the potential to drive the process and the shaping of the learning space that is constitutive to this process (cf. Barron, 2006; Damşa *et al.*, 2010). With regard to human agency, Snow (2001) emphasizes the active, wilful character of actors and asserts that they neither respond exclusively to internal directions nor are passive receivers of structural/social messages and constraints. Learners might not always have a clear

idea that they are co-constructing (meaning, knowledge, practices), yet co-construction and participation are emerging, and not always because learners carry with them already formed understandings of what they should do for learning. Rather, it is because there is an emergent constitutive order that cannot be attributed only to the individual mind because it involves an unfolding field of action (Damşa & Jornet, 2016). It is important to note that, according to the conceptualization we propose, learning spaces are enacted by learners but not (necessarily) in the way envisioned by the teacher or outlined by the learning design. Because learning design is the process of preparing situations and things for others to learn (Goodyear & Dimitriadis, 2013), the enactment may build on this design but only to the extent learners consider the design to be instrumental for their needs.

Relational and spatial natures

Principles C and D connect to other pivotal aspects of learning spaces, namely, spatiality and distribution of resources that enable co-construction and enactment. The more common objectivist position, wherein space presents as self-evidently material "in the sense that it appears as the material pre-set stage for human action … [and] also as buildings and architecture" (McGregor, 2004, p. 245) is problematized from an ecological perspective. An objectivist perspective argues for space as a neutral framework *for* human action or, under some circumstances, a deterministic understanding of spatial structures, a 3D container for action (McGregor, 2004). Spaces are thus seen as support systems, given rather than made, and not part and socially constitutive of how humans learn. As Mulcahy (2018) claims, an "agential cut" is made between learning spaces as support systems and human learning.

This is a problematic view of learning spaces because it neglects the fundamental presence and role of learning as a universal practice that includes epistemic, relational, institutional, digital and/or material elements. Hence, an ecological, relational perspective on learning spaces seems more appropriate since it implies an understanding of learning spaces beyond their material structural entities (school, lecture hall, museum), which display properties and qualities separate from the practice of learning. Space is understood, rather, as "a product of relations, relations that are necessarily embedded material practices which have to be carried out" (Massey, 2005, p. 9). This outlines the relational nature of learning spaces, which accounts for the idea that "space is something generated by interactions and interrelations, and that space generates interactions and interrelations" (Gulson & Symes, 2007, p. 17).

Summing up the aforementioned stance, we construe learning spaces as *customized versions of the learners' activated ecologies of resources available in various contexts, facilitated by pedagogical arrangements and educational infrastructures but enacted by learners through agentic co-construction and relational endeavours.* Along these lines, learning spaces are immaterial, constitutive of practices, (co-) constructed by learners, and shaped by the learners' needs and goals. In this construction process, tapping into various ecologies of resources that are epistemic, relational or digital material becomes an organic, iterative, self-driven enterprise.

Co-constructed learning spaces: An empirical illustration

In this section, we present a vignette that illustrates how a group of undergraduate students co-constructed their learning spaces by drawing upon different ecologies of resources. The illustration is grounded in empirical work conducted in a large research project on student learning, with the context being a first-semester software engineering course. This case (Yin, 2013) was selected due to its potential to display aspects of student-driven learning activities, particularly independent enquiry and the way it capitalizes on various resources for the learning process. The vignette was created based on a larger data set, including observations of lectures and lab

sessions, recordings of group discussions and interviews with participating student groups. The *original* thematic analysis (cf. Braun & Clarke, 2006; see Damşa & Nerland, 2016) sensitized us to certain aspects of the participation in and challenges with collaborative enquiry in the software engineering domain as well as to working with domain-specific tasks and resources.

The empirical case: A web development project

We observed and documented an introductory course in web design and development—Web Project (10ECTS)—which had about 120 students enrolled. Sixteen students (2 female and 14 male) who voluntarily agreed to participate in this study were organized into four groups, and their group work was followed in an ethnographic fashion for 20 weeks. Biweekly lectures over the course of seven weeks introduced the students to programming languages for web design and development (eg, HTML5, CSS, PHP, JavaScript). Eight other lectures introduced students to project management concepts. In biweekly lab sessions, students worked on individual assignments. A large collaborative assignment consisted of an eight-week-long group *web development project* (see Figure 1). Resources provided in the course included lectures, a textbook and a number of web-based applications, including a repository hosting platform (GitHub), a virtual platform containing tutorials and references (www.w3schools.com), and a code validation tool. The teacher was available to give feedback; the lab leaders were incidentally available for technical guidance.

This collaborative project required the groups of students to employ programming languages and strategies to develop a functional website of their choice, and they were tasked with documenting their technical decisions and management strategies. The groups had the ability to use the school's infrastructure to access course resources and to ask for guidance, but were also invited to organize their work and access the free resources typically used in the field of web development. The pedagogical arrangements for the group project (preconfigured by the teacher) mainly outlined the type of product to be developed, identified types of (discipline-specific) activities and

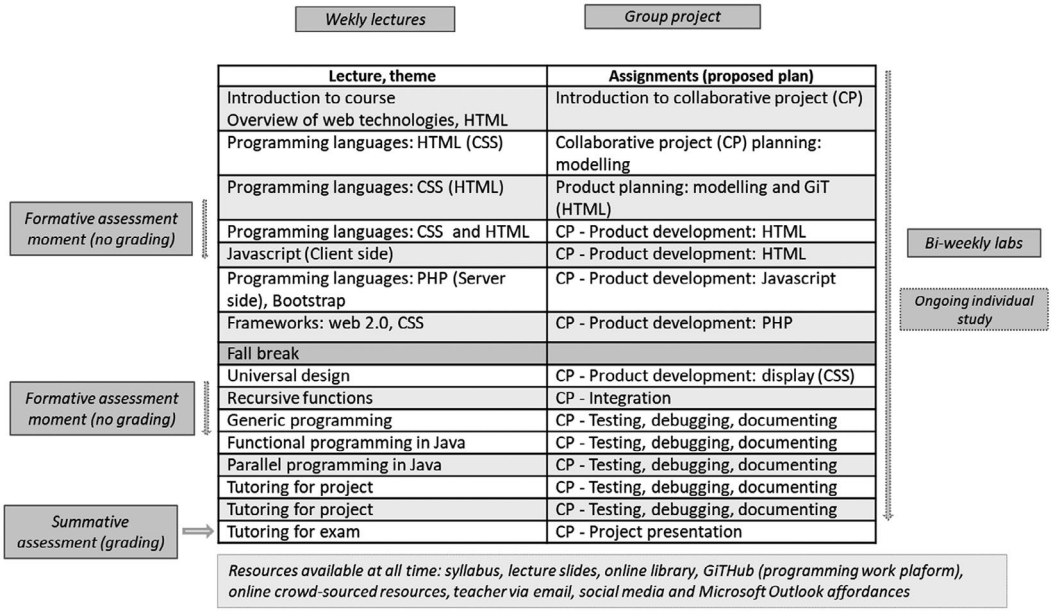

Figure 1: Overview of course and project work (based on original analysis)

competencies needed to achieve this, and the resources provided in the course (e.g. physical meeting places, feedback from the teacher, digital resources). The students were explicitly informed that they had to organize and perform the collaborative project using these resources but they were not necessarily limited to using only them.

Data snapshot

The student group whose activity we analysed had a collaborative approach to programming. While struggling with working quickly and efficiently, this group was thorough in solving the problems they encountered by sitting together to discuss the problem or through individual efforts followed by the sharing of alternative solutions. The group used Dropbox as shared storage space, GitHub to program, a Facebook group to communicate and a series of online crowdsourced platforms as resources for their work. In addition, they used a variety of strategies to reach out to several other resources online.

In the data snapshot shown in Figure 2, the group is represented in their regular group work set-up that they created in a small room assigned for group activities. One member always brought a projector, which was connected to one of the laptops. All members had their own equipment in the form of, for example, laptops or smartphones, which they used in parallel with the work projected on the screen. As the observation data unveiled, group members would sit together for long hours, often programming live so that everyone in the group could see, follow, contribute, comment or object. In addition, they created a shared repository of resources and ideas they were working on without being guided in the process.

In the discussion excerpt shown in Table 1, we show how the group worked through a challenge in their programming project. In this meeting, one student had just arrived, so the others began updating him because he had missed the first part of the meeting. They had worked on a body mass index (BMI) calculator, which they wanted to have on the website so runners could measure body mass. The group had been struggling to make sense of how the BMI calculator could be developed, and they were examining various resources to determine if and how these resources could facilitate development.

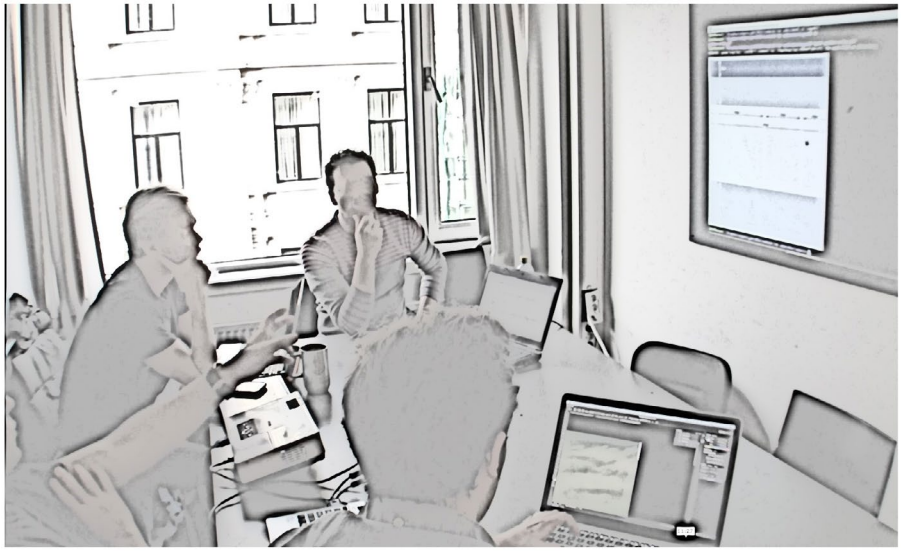

Figure 2: The set-up in the group room

Table 1: Excerpt of group discussion

1	S1	We have such a calculator made in **JavaScript**? (*shows calculator on their website made with JavaScript*)
2	S2	Yes, I understand
3	S1	Okay... ehm... (*switches to front page*) And then we have one [calculator] that is made in **PHP** (*opens the calculator in the programming window made in PHP*), that uses **GET**, and then it must, it calls that one, what's it called... yeah. If one likes this, then that one form calls itself (*enlarges image*)
4	S2	Yes. Yes
5	S1	And then I do not think we... we would have needed to call that **jQuery** which... a forward-loop. (*switches to programming window*)
6	S2	Yes, what you, what you can do to avoid that (*S1 scrolls down*) is either to write in JavaScript or use **Ajax.** [...]
7	S1	Mhm. That I don't think we have time for, but...
8	S2	If you go to the API.jquery.com
9	S1	But it is made with cookies and everything that (*switches to browser*) ugh, yes. API jQuery? (*inserts search term in **Google***) (*clicks on link*)
10	S2	Ehm... yes... ehm... and then yes, either **POST** or GET
11	S1	Try with GET then. (*inserts search term*)(*scrolls down*) Uhm...that one maybe? (*pointing at screen*)
12	S2	Yeah... let's see. (*S1 scrolls through the hits*) Now I don't remember exactly, but it should be an Ajax category, maybe. [...]
13	S3	If we look at all, all that have if you search for... (*gesturing towards something on his screen*)
14	S2	Yes that's the one
15	S3	Submit without reloading or something, then it always says that you must use **iFrames** then
16	S1	Yes
17	S1	Now but I think we'll choose a simple for-loop to reach the goal, we would preferably (*scrolls down on the page*)
18	S2	It is in fact not really that much, much work with this type of BMI calculator when using Ajax really
19	S1	No. This, that is clear it's just that it... it has already taken a lot of work to... (*switches programming window*) read the cookies you know. And... like it is now, (*scrolls down through the code*)... we thought that if we are unable to accomplish that... but we will make it now

Finally, in the group interview conducted at the end of the project period, the group indicated that the repository was their way of dealing with their need for working with resources that were not provided in the course and for dealing with the complexity of the programming project.

A co-constructed learning space in the collaborative project

The case of the student group engaging with their web development project provides an illustrative example of how a collaborative learning space is created by capitalizing on an existing infrastructure, the current pedagogical arrangements, and the task being envisioned (see Figure 1), in this case, provided by the course and the teacher, but which was accomplished through the students' enactment, engagement and sustained effort in tapping into other pools of resources. The students capitalized on the physical infrastructure within the school using the room for their group work (see Figure 2), creating a confined space where they engaged with project work together. Per Principle D, the infrastructure of the school represented an arena that facilitated the interaction, yet the practical details were defined by the students. The group created routines around the use of the office space and other available facilities as well as with the sets of materials—the projector and their individual devices (eg, laptops, mobile phones, chargers)—and

with a virtual context (eg, repository, programming languages, digital tools), being constantly employed in their programming work and group discussions. The domain of software engineering is characterized by typically abundant web-based resources, and these students sought access to that rich ecology of resources. They created a combined physical and digital/immaterial arena for accessing and assembling those resources they felt they needed to accomplish the complex, ill-structured task. While some of the resources they employed had been provided in the course, many more were accessed by reaching out in specialized virtual environments (crowd-sourced sites, programmers' communities) or by building relational ties with experts within the school environment (lab assistants, teachers) and beyond (experts online, customers, other informal connections in the programming field). The relational nature of the students' learning space (as noted in Principle C) was enacted through the way the students assembled and capitalized on spatiality (ie, they made the room their co-located work hub) combined with how they navigated in and out of this set space to access and employ resources distributed amongst various ecologies of resources.

The relational nature of this space is also evident in the momentary snapshot provided by the discussion excerpt. In the excerpt, the students relate to (1) each other by communicating about ideas, alternative solutions and resources through gestures and manipulation of devices; (2) the course curriculum and the teacher by referencing the lecture material and feedback comments, along with the teaching assistant, who was asked to drop by to answer some questions; (3) various web-based programming resources situated beyond the course boundaries, which the students brought in either through conversation or by browsing; and (4) material resources that they included in the activity in the form of using the room, manipulation and pointing.

The provided excerpt reveals nine programming resources (text in bold in Table 1) that the students engaged with. These programming resources are not only mentioned, but also accessed and manipulated during the conversation, while the students are trying to understand the problem related to their programming work. We can see in the text (lines 3, 9, 11 and 19) that group members were searching the web for these resources and engaging with them while attempting to find alternative solutions to their problem. This is a collaborative process, with some group members proposing search solutions and paths and others commenting, trying out, or executing potential actions. At all times, the students were relating to each other's ideas and to what the resources could provide to help them arrive at a solution. For instance, at lines 11 and 12 in Table 1, the students engaged in a longer process of scrolling through and examining results, with S2 having to recover the necessary categories for tackling the task from memory and S1 indexing towards present results at their disposal. The relationship between previous, externally assembled knowledge is dialectic and extended from relational experience from interpersonal interactions and gesticulations towards the online material (screen). Principles A and B, which stipulate that learners co-create their learning space, are illustrated here by the contributions and actions where the students related to each other in various ways, but which converged and became particularly visible during the face-to-face discussion. Moreover, Principle C, which postulates the relational nature, becomes apparent here as well: the learners have to interact and command their attention towards elements that are both immanent in their own private learning and extensive from their dialectic interaction with their environment. In addition, the emphasis on eventualities during the task was a further sign of the indeterminacy of the learning structure, which was mutually reinforcing, scaffolded on previous and immediate resources, and also contextualized in the broader setting of the task and assessment of the options at hand ("That one maybe?" on line 11, and "choose" and "preferably" on line 17 in Table 1).

The empirical example that was briefly examined in the previous section offers a brief but clear insight into a space where the students were familiar with one another, each other's ideas, the

infrastructure they had created in the room, and the resources they had accessed. The students had taken charge of that place in regard to both space and activity, and they were driving the process. As reported in the group interview at the end of the project period, these patterns emerged out of curiosity about the topic they were working on and the ambition to become proficient in the programming skill at stake. In this vein, the students showed a rather advanced sense of agency (as in Principle B) by setting out on a course to co-construct a learning space with a combined material, virtual, relational and intellectual nature and pursue their learning goals by capitalizing on the resources they gathered together. The learning space the students co-constructed had linkages to and capitalized upon on an extended ecology of resources of varying natures, communities of practice, institutional and digital material infrastructures and their own efforts and collective input.

Discussion

This contribution set out to argue that the salient ways of viewing learning and learning spaces do not do justice to the constantly reconfigured contexts and processes of learning. In complete acknowledgement that the role of digital technologies is paramount in relation to learning, we proposed a conceptualization of learning spaces that draws upon an ecological perspective. This perspective depicts learning as a non-linear, iterative exercise in rational conflict, which challenges the sense of learning closure. It maintains, rather, that learning is a transformational phenomenon that influences the learner holistically and interactively, in defiance of reified divisions between agentic subjects and material objects. Ultimately, learning spaces are, in fact, the very arena in which such processes emerge, and at the same time, the spaces themselves take specific forms through the way learners and others act and interact. This paper suggests a set of principles that highlight the relational and emergent character of learning spaces, emphasizing the paramount role of students in co-constructing them.

The briefly examined empirical example of the software engineering students offers an insight into how the students took charge of the process of constructing their learning space by defining the physical spatiality, assembling resources, adapting local infrastructure and interactively driving their development project forward. These patterns emerged out of their curiosity about the topic they were working with and the ambition to become proficient in the programming skill they were learning. In this process, they harnessed a vast array of iterative, non-reified programming resources which were complemented by their prior knowledge and experiences, their assessment of available choices and their material and digital environments.

Naturally, this process did not appear independent of the educational context and pedagogical framing. Physical places were provided by the educational institution. The course and pedagogical arrangements offered a framework for the students' work and suggested entry points to a wider ecology of resources within the programming domain. However, in order to manage and sustain their learning process, the students needed to appropriate and create their own space within this wider landscape of opportunities. As noted earlier, a learning space represents an arena where learning can be nurtured by employing resources gathered from various broader ecologies of resources (Luckin, 2008). In our example, this active assembling was even necessary to sustain the learning process due to the open and distributed character of knowledge resources and professional activities in this domain. The institutional structures, course curriculum, and activities all provided the students with the validated knowledge about web design and development that was necessary for engaging in the project work (labs, tutorials, guidance and feedback). But the learning space of the group was not fully determined by these elements. Rather, these elements provided only the vantage point and the foundation (of epistemic and digital material nature)

upon which the students could begin creating their *own* learning space. We can clearly discern that the learning space was not fully predefined by the teacher or determined by the course structures but rather was co-constructed, articulated and maintained by the students, based on their own needs and through their efforts of collaborative programming and project management.

Essential features of a learning space comprise the learner's agentic conduct that drives a process of assembling resources of varying natures that are provided within an institutional context. But these resources also come from beyond that context, including from continuously relating to environments, people, tools and sources that can feed the process and support advancement in knowledge and competences. At the same time, framing conditions provided by the institutional context are critical for embedding the learning space in an environment that facilitates and fosters learning rather than imposing expectations that are distant from the learners' realities. An ecological view accounts for the learning space being organically embedded within institutional frameworks but also being permeable and open to crossing the boundaries of these frameworks (cf. Akkerman & Bakker, 2018; Barron, 2006). From an educational practice perspective, this study raises questions related to whether knowledge and competences of relevance for students' futures (professional and otherwise) are, in fact, sufficiently considered in the way institutionalized education supports and fosters efforts for creating and maintaining learning spaces that match students' needs and that facilitate access to resources.

These insights direct us to the importance of design *for* learning; in other words, the process of translating abstract principles about learning into workable solutions in a way that provides opportunities for learning instead of imposing structures (Kali *et al.*, 2015). Such designs should not be understood as pre-made configurations of course elements but, rather, as dynamic arrangements, open for adjustment to the emerging needs of an increasingly diverse student population. The teacher/designer can specify learning goals and propose activities, while the learners can construct their own interpretation of the requirements for a designed task and work accordingly. The responsibility for how learning happens is situated at the intersection of the teacher's and students' responsibilities (Goodyear & Dimitriadis, 2013). The aim of fostering the creation of learning spaces that are learner centred is then best served if teachers (or institutions) work towards designing situations and environments that provide scaffolding for productive and meaningful student engagement and construction of their own learning spaces. These environments involve a combination of educational activities that provide for eliciting a variety of possible behaviours, experiences and learning approaches from learners and which are to be interpreted and pursued (used) by learners. In this sense, learning spaces can be "contingent and locally inhabited" (Goodyear & Dimitriadis, 2013).

In this paper, we have proposed a number of underlying principles that pin down the essence of an ecological perspective on learning and learning spaces and can offer a direction for empirical, analytical and learning design efforts. Further research is necessary to document and provide deeper insight into learners' awareness of the responsibilities, opportunities and privileges that come with shaping their own spaces. Both empirical and conceptual accounts are needed to generate a comprehensive understanding of how the extended ecologies of resources can feed into student-shaped learning spaces that are permeable, unbound, and in a closer relationship with extended ecologies of resources.

Conclusion

By employing an ecological perspective on learning spaces, this paper advocates for an indeterminate, open reading of the way such spaces are co-constructed through students' sustained efforts and engagement. This ecological perspective promotes a fluid, iterative, and self-corrective

interpretation of learning that defies a strict division between the learners' material spaces of knowledge and their interpretative community, while at the same time, it invites active coalescence of emergent technologies with new, contextual learning functions. We showcased the merits of such an ecological approach through an example from a course in web design and development in which the learners, through a variety of practices, illuminated the emergent, expansive, interactive and synergetic approach to addressing learning tasks. The empirical findings presented here and elsewhere (see Damşa & Nerland, 2016), as well as their theoretical underpinnings, prompt us to surmise that, to provide for the successful construction of learning spaces that are safe, resource-rich, and conducive to learning, educational programs should provide not only the framing conditions for learning but also the flexibility and permeability required to access extended ecologies of resources made available by digital technologies.

This contribution has added new dimensions to existing vocabularies that allow for an interactive and plural understanding of future learning spaces. Combining the insights from different epistemological perspectives allowed us to capture some of the irreducible complexity of the student experience in today's arenas of teaching and learning. Ecological thinking carries several positive implications because it encourages consideration of the uncertainty generated by the increased connectedness and flow between, on the one hand, the roles of students and teachers to knowledge validation, discovery, and creation and, on the other hand, technologies and spaces. At the same time, this way of thinking provides a conceptual apparatus that accounts for the idea of learning being at the centre of these spaces.

Ultimately, the line of enquiry pursued in this paper could enrich several aspects of the salient pedagogical discourse. An ecological approach has the potential to provide a critical foil for rethinking the changing role of students in relation to educational environments. What's more, it can reorient current pedagogical practices and designs towards more emergent learning spaces. In this way, an ecological perspective also provides fertile ground for promoting studies of practices in the emergent field of education for sustainable development. This has the potential to advance prospective, long-term thinking about the educational design of learning technologies that views it as an empowering medium for engaging learners in the creation of their own learning spaces.

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Statements on Open Data, Ethics and Conflicts of Interest
Original data during this research are stored on secured server at the University of Oslo. The relevant data from the current data set can be made available by contacting the corresponding author at crina.damsa@iped.uio.no.

The data were handled in accordance with the new GDPR as it is enforced at the University of Oslo, ensuring the protection of participants' privacy. Data collection and use is conform to the BERA ethical guidelines for educational research. The data used in this study was anonymized and original data is being deleted at the end of the project.

No conflict of interest exists in the submission of this manuscript. The authors declare that the work described in this paper is an original research that has not been published previously and is not under consideration for publication elsewhere, in whole or in part. All the authors listed have read and approved the enclosed manuscript for publication.

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