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Learning activities as enactments of learning affordances in MUVEs: A review-based classification

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Abstract Three Dimensional Multi-User Virtual Environments (MUVEs) are promising tools in education because of the unique affordances they offer. These learning affordances imply certain actions that in turn can lead to corresponding learning activities. There seems to be a lack of reports on which of the affordances of MUVEs for learning and teaching are used and how they are enacted by relevantly designed learning activities. This study investigates the learning activities conducted in Second Life, the most popular and widely used among the "sandbox" type MUVE platforms, as reported in 205 empirical studies, by associating them with the learning affordances they enact. As necessary step towards this goal, the study proposes a new classification of learning affordances of MUVEs and a new concrete set of learning activities based on the literature review. Learning affordances include free navigation, creation, modeling and simulation, multichannel communication, collaboration and cooperation and content presentation and/or delivery. By using the open, axial and selective coding offered by the grounded method, the learning activities that emerged from the exhaustive empirical review, are well associated with the proposed six learning affordances, validating in return the functionality of the proposed set of learning affordances. The five more general learning activities, resulting from the selective coding, are content creation, content exploration and interaction with content, social interaction, gaming, participation in representations of real life events and situations. Further research on other MUVEs is needed to establish this framework.

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1 Introduction

Three Dimensional (3D) Multi-User Virtual Environments (MUVEs) are online 3D virtual environments that allow many users, being represented by avatars, to simultaneously log in, communicate and interact with each other and with the virtual environment. MUVEs are promising tools in education because of their potential to enhance learning experiences. However, technology itself does not cause learning. The technological characteristics of Information and Communication Technologies (ICT) afford actions that may be used in teaching and learning and consequently lead to learning benefits (Kirschner 2002). It is the pedagogical use of ICT and the perception and enactment of learning affordances of the environment by designing and implementing meaningful learning activities that may lead to learning outcomes (Dalgarno and Lee 2012)..

3D MUVEs can be considered as a combination of Virtual Reality (VR) and Computer Supported Collaborative Learning (CSCL) environments. MUVEs are also called Virtual Worlds (VWs), both terms clearly referring to VR technologies. This is not the case with the umbrella term “Virtual Learning Environments” which should not be confused with VR and is commonly used in the e-Learning domain, referring to Learning Management Systems, Course Management Systems, or Knowledge Management Systems. As Dalgarno and Lee (2010) report, the basis of the three spatial dimensions is essential to virtual worlds and consequently they are characterized as 3D. VWs are collaborative environments usually accessed through the Internet and are synonymous or similar to MUVEs (Duncan et al. 2012). Some of the most popular “sandbox” type MUVE platforms, that can be used for many purposes across many domains in educational settings, are Second Life® (SL), Active Worlds®, OpenWonderland®, and OpenSimulator®.

3D MUVEs have been around for many years now. The ‘hype’ surrounding MUVEs, especially in the field of education, is fading away and the technology behind them, namely Virtual Reality, is now being considered more realistically in terms of benefits and practical applications, as its actual potential is becoming widely understood.

An important issue in making the most of MUVEs in education is to understand the affordances of the technology and consequently, to understand how to design learning activities that enact all of those affordances.

Despite the increasing number of articles and reviews on learning and teaching in MUVEs, there is a lack of reports on which of the affordances of MUVEs for learning and teaching are being used and how they are enacted by relevantly designed learning activities. This information would be very useful for educators, researchers and developers as it could provide an understanding on how MUVEs are used for teaching and learning, if their pedagogical potential is used and could highlight any inherent difficulties in enacting some affordances.

This paper investigates the learning activities of empirical studies conducted in MUVEs through a literature review, by associating them with the learning affordances they enact. As a necessary step towards this goal, the paper discusses and proposes a concrete set of learning affordances of MUVEs.

2 Learning activities and a new set of learning affordances in MUVEs

There are only a few studies that report on the learning activities in MUVEs. Ryan (2008) presents 16 ways to use Second Life (SL) in the classroom. Among these, there are learning activities such as role-playing as well as other type of actions such as anonymity creation and recruitment. Inman et al. (2010) propose a series of potential uses of SL in K-12 and Higher Education having analyzed "student activities" in 27 relevant empirical studies. The student activities include lectures or attendance in virtual seminars, participation in surveys, role-playing activities, exploration of design and space, game play or game creation, as well as participation in group projects. Hew and Cheung (2010) in their review of 15 empirical studies have found three uses of VWs, namely communication, spatial simulation and acting. Duncan et al. (2012) describe a series of "educational activities" in their review of 100 relevant resources. The authors refer to ways of "teaching and learning" rather than learning activities since they present instructional strategies such as problem based learning and enquiry based learning. Dalgarno and Lee (2012) conducted a grounded analysis based on a survey with 53 educators and present 10 categories of learning activities in 3D VLEs. Among them, some categories include instruction, something that cannot be characterized as a learning activity. Reisoğlu et al. (2017) in a meta-review focused not on learning activities but on learning strategies, examined 167 empirical studies that involve the use of 3D VWs in education. They report that collaborative and exploration based learning strategies have been used most frequently in 3D VLEs.

The literature on digital learning environments and especially on 3D VLEs and MUVEs shows that researchers have different views on the characteristics of affordances. MUVEs afford certain actions that lead to corresponding learning activities. Therefore, there is a need to classify affordances that contribute to learning, namely learning affordances, as well as their association with learning activities. As a result, instructional design in MUVEs is expected to be more effective.

The term "affordance", firstly introduced by Gibson (1977), is an agent's perception of the environment in terms of afforded actions. In Norman 1988, Norman uses Gibson's idea in the field of user interfaces and presents the term "perceived affordances", where the agent knows about the environment and considers some actions of the environment as salient. According to Norman, "affordances define what actions are possible". An affordance is the property of objects that convey "important information about how people could interact with them" (Norman 2013). Hartson reinforces Norman's approach and proposes four types of affordances in the field of interaction design (2003). Also in 2003 Michaels defines affordances as "the actions permitted an animal by environmental objects, events, places, surfaces, people, and so forth. An action is understood as a goal-directed movement (or non-movement) that entails intention, the detection of information, and a lawful relation between that information and the control of movement". Michaels points out that affordances "exist independent of being perceived" and "are specified by information and may be perceived". She also points out that the affordances "are not defined with respect to particular animal effectivities”, that is “the properties of the animal that allow that action to take place in the environment”.

Kirschner introduces the term “educational affordances” as the “characteristics of an artifact that determine if and how a particular learning behavior could possibly be enacted within a given context” (Kirschner 2002). Dickey (2003) uses the term “pedagogical affordances” in a similar way to reveal the opportunities offered by the 3D VWs for knowledge construction. Dickey presents the affordances of synchronous discourse tools that provide “opportunities for immediate exchanges and interactions”, as well as “opportunities for exploration and manipulation to foster the construction of new knowledge”. Hollins and Robbins (2008) alternatively use the terms educational affordances and pedagogic affordances referring to identity, space, activity, tools and community. In Dalgarno and Lee 2010, Dalgarno & Lee introduce the term “learning affordances” to describe the tasks and activities a learner may enact in a VLE, tasks that may lead to learning benefits. They claim that learning affordances are the result of VLEs used to facilitate learning tasks that “lead to the development of enhanced spatial knowledge representation”, “would be impractical or impossible to undertake in the real world”, “lead to increased intrinsic motivation and engagement”, “lead to improved transfer of knowledge and skills to real situations”, and “lead to richer and/or more effective collaborative learning”. Gamage et al. (2011) investigate teachers’ perceptions of learning affordances and propose the affordances of “flow”, “awareness and co-presence”, “emotional connection”, “authentic 3D experiences”, “artificial 3D experiences”, and “role-projection”. Warburton (2009) refers to “affordances (of SL) for education” instead of defining affordances as educational, pedagogic or learning. Warburton’s affordances for education include “extended or rich interactions”, “visualization and contextualization”, “exposure to authentic content and culture”, “identity play”, “immersion”, “simulation”, “community presence”, “content production”.

The terms “educational” and “pedagogical” are more general than “learning”. They incorporate affective and psychomotor domains, social issues, etc. This study is about learning, so we prefer to use the term “learning affordances” as proposed by Dalgarno and Lee (2010). Furthermore, with respect to the existing classifications, we do believe that a new set of learning affordances should be proposed in order to provide a more consistent association among the learning affordances and the “afforded” learning activities. This new proposed set should follow the unique characteristics of the technology used, namely VR and MUVEs. This approach is also in accordance with Michael’s ontological definition of affordances that have to be based on the salient characteristics of technology (Michaels 2003).

The affordances of VR and MUVEs include multisensory intuitive and real time interaction, immersion, presence, autonomy, natural semantics for the representation of objects and facts inside the virtual environments and worlds, users’ representation through avatars, first-person user point of view, first-order experiences, size in space and time, transduction and reification (Mikropoulos and Natsis 2011). We propose the following classification of six learning affordances resulting from the affordances of VR and MUVEs as:

1. free navigation
2. creation
3. modeling and simulation

4. multichannel communication
5. collaboration and cooperation
6. content presentation and/or delivery.

The learning affordance of free navigation comes mainly from the affordances of 3D spatial representations, first-person user point of view and first-order experiences. Free navigation refers to actions like meaningful virtual fieldtrips and tours, as well as game play such as scavenger hunts.

Creation comes mainly from multisensory intuitive, real time interaction and natural semantics. The learning affordance of creation involves building and scripting and refers to actions like the design of a virtual learning environment, building a virtual building, writing the code for the behavior of a virtual object, and course content design.

The learning affordance of modeling and simulation rises from almost all of affordances and especially from size, transduction and reification, and encompasses visualization. Actions referring to modeling include data presentation and interpretation, while simulation and visualization follow modeling and relate to the reproduction of a real system, the imitation of a natural phenomenon, a virtual experiment. Game creation and the design of environments are among the activities that refer to modeling and simulation.

Multichannel communication comes mainly from the affordances of multisensory intuitive and real time interaction as well as the users' representation by avatars. Communication relates to actions such as discussions, chatting, lectures and conferences.

The learning affordance of collaboration and cooperation rises from all the affordances and is enhanced by the presence a participant might sense. Collaboration and cooperation relate to actions like meetings, role-play, and social interaction.

Content presentation and delivery comes from all affordances and especially from tools like SLOODLE and shared interactive whiteboards. Content presentation and delivery relate to actions like presentations and exhibitions.

When comparing the above proposed six learning affordances with those presented in the relevant literature, one can see overlaps as well as differences. An example of an overlap exists between the learning affordance of "communication and collaboration" and "representations and simulations" proposed by Cunningham and Harisson (2011). The differences in the literature refer to technological aspects, effectivities and instructional techniques that various authors present as learning affordances. More specifically, among the affordances for education, immersion and community presence Warburton (2009) proposes affordances that we claim as generic affordances of VR technologies. Gamage et al. (2011) also support this claim. They propose awareness, co-presence, and emotional connection as learning affordances. Dalgarno and Lee (2010) propose five affordances by describing as such the potential of 3D VLEs in facilitating various tasks but as long as these affordances reflect effectivities, they cannot be included in the proposed set. Cunningham and Harisson (2011) present "scaffolds", that is an instructional technique rather than a learning affordance.

It seems that there is a need for clarification and classification of learning activities and their association with learning affordances and consequently with the perceived learning benefits as proposed by Dalgarno and Lee (2012). The main reason is that in order for one to use effectively a digital learning environment they have to know its affordances and limits, as well as the learning activities afforded by the environment.

3 Methodology

The aim of this literature review is to investigate the learning activities conducted in empirical studies of MUVEs, associate them, and consequently, validate them with the six learning affordances proposed.

The review refers to studies on Second Life (SL), the most popular and widely used among "sandbox" type MUVE platforms (Diehl 2008; Kirriemuir 2010, 2012; Eaton et al. 2011; Wang and Burton 2012). Second Life seems to be the most frequently preferred virtual world platform, because of its flexibility and convenience for users and designers who want to design 3D VWs for learning (Reisoğlu et al. 2017).

The grounded method (Strauss and Corbin 1998) has been used as it is a valuable method for rigorous literature reviews (Wolfswinkel et al. 2013). Furthermore, the grounded method is in line with the aim of the present study which is not only to report the learning activities where other qualitative methods such as qualitative content analysis would be more suitable, but rather to "reach a thorough and theoretically relevant analysis" (Wolfswinkel et al. 2013) of the topic "learning activities" and its relation to the proposed set of learning affordances.

3.1 Literature search process

An extensive literature search was conducted via academic electronic databases (ERIC, JSTOR, MUSE, PapersFirst, Science Direct), organizations (ACM, American Chemical Society, American Institute of Physics, IEEE, Institute of Physics, Psych Articles), publishers (Cambridge University Press, Kluwer Law International, Mary Ann Liebert, MIT Press, Oxford University Press, SAGE, Springerlink, Taylor & Francis Group, Wiley Interscience) and the Lindens Lab's academic database (SL Workshops). The term "Second Life" was used to search for initial articles. The "snowball" method followed for a more comprehensive search.

3.2 Inclusion and exclusion criteria

The review includes peer-reviewed empirical studies in SL published as full length articles written in English in scientific journals, proceedings of international conferences, as well as workshops from SL's introduction in 2003, until June 2016. The studies referred to the implementation of SL as a form of in-world learning activities in mainstream educational settings. Therefore, studies with participants other than students (Oh and Nussli 2014) or studies that did not focus on learning experiences (Nakasone et al. 2009) were excluded. In addition, studies reporting activities for SL are not part of the sample. Thus studies like the creation of a manual (Wang and Shao 2012) or the design of a survey concerning SL (Minocha and Reeves 2010) were excluded. Finally, studies that evaluate the technological features of the platform (Attasiriluk et al. 2009) or the psychological aspects concerning its use such as the issue of identity (Park and Seo 2013) were also excluded.

A total of 205 articles meeting the inclusion criteria on the educational uses of SL published between 2003 and June 2016 were found. Relevant empirical studies were not found before the Linden Lab's SL workshops in 2006 and 2007.

3.3 Classification process

The classification process concerning the learning activities in MUVEs had as its basic unit of analysis each individual paper in the sample and it was conducted according to the three analytical coding steps proposed by Wolfswinkel et al. (2013). The first step of open coding resulted in the inductive immersion of the themes that reported the learning activities which students were involved in SL. This process resulted in certain categories of activities. These provided the corresponding groups of activities according to the axial coding process. Finally, the general categories of activities identified during the selective coding process were configured. The coding process was done by two coders. Two different coders studied all the articles and resulted to common themes at a 90 % consistency rate.

4 Results and discussion

Table 1 shows the 47 categories of the learning activities found during open coding, the 19 categories from the axial coding process, and the five categories identified in the selective coding process.

The learning activities recorded during the first step of open coding can be considered as examples and therefore they do not form an exhaustive list. They are presented analytically for every discipline. The axial coding activities are more general activities and are associated with the learning activities reported in the literature. The selective coding learning activities present a more general level of abstraction that wouldn't enable any changes. This helps to associate learning activities to learning affordances. Table 1 also presents a top-bottom hierarchy of complexity.

4.1 Computer science

Forty three empirical studies were found where SL was mostly used as a programming environment. Crellin et al. (2009) asked students to collaboratively build a balloon debate classroom or participate in the design of engineering projects (Heads-Up Display, PC hardware, a webcam and university's places). Focusing more on scripting, researchers had asked students to design an adder or a Mealy machine (Ritzema and Harris 2008), or interface prototypes (Calongne et al. 2008. Others gave more freedom to students in their project development either collaboratively (Cargill-Kipar 2009), or not (Esteves et al. 2008, Esteves et al. 2011). Students were also involved in the collaborative creation of VLEs such as a health information environment (Hansen et al. 2008, Good et al. 2008). Hwang et al. (2008) had designed a set of building activities regarding basic skills of spatial reasoning.

A different approach is presented by Girvan et al. (2013). Papert's microworld was replicated in "SLurtle" combining the Scratch4SL programming environment.

Table 1 Classification scheme of learning activities

Selective coding	Axial coding	Open coding
Content creation	Building Scripting Multimedia design Environment design	Build object Build building Script code Create exhibition content Create animation/machinima Design landscape Design environment
Content exploration & interaction with content	Interaction with content Interaction with simulated environments Exploration of concepts through visualization/modeling	Manipulate object Interact with bot Explore visualization Explore model Watch & present slideshow/presentations Watch videotaped lectures Explore instructional material Explore lab/simulation
	Place exploration	Tour Field trip in plant Field trip in touristic / historical place
Social interaction	Tutorial session delivery & attendance	Attend lecture Deliver lecture Attend conference Participate in tutorial meetings
	Communication	Communicate for task completion Discuss in discussion/meeting SLOODLE Communicate with mentors Communicate in multidisciplinary context
	Interviewing	Conduct interview
	Collaboration & Cooperation	Collaborate / Cooperate in task completion Collaborate in games Practice collaborative techniques
	Role playing	Play role Play role in a simulated environment Play role as intern
Gaming	Game play Game creation	Play with specific game content Play in game environment Play role inside game Play scavenger hunt Play quiz
Participation in representations of real life events & situations	Virtual internship Communication/collaboration with company Virtual participation in social events & actions	Participate in working scenario Work in virtual company Communicate with real vendor/purchaser Collaborate with company Participate in social event Shop Participate in scenario of accident

Scratch4SL was also used by Pellas and Peroutseas (2015) to enhance students' programming skills.

Instructional material concerning algorithms has also been developed in SL. The activities concern students' interaction with content, for example selecting the correct data structures or algorithms (Lim and Edirisinghe 2007; Wei et al. 2009; Moffat and Trinder 2009). SL was studied by Herold (2010) and Mabrito (2012) as a medium for students' visits to virtual towns. Students have also collaborated in activities using Sloodle, metabots and learning objects to clarify abstract concepts (Griol et al. 2012).

Communication among students for the completion of collaborative projects is another type of learning activity in SL. Students have created a machinima project on digital media (Gonzalez 2007; Thomassen and Rive 2010), while others communicated in order to solve algorithmic and programing problems (Moffat and Trinder 2009). Olteanu et al. (2014) report that students increased their collaboration by designing a virtual course, while others aimed at communication per se (Tapsis et al. 2012). Others focused on techniques to teach collaboration to students by using the jigsaw and fishbowl technique in SL (Tsiatsos et al. 2009; Konstantinidis et al. 2010).

Gaming is another activity in computer science. Ye et al. (2007b) as well as Wang and Zhu (2009) have applied Groupthink and SimSE (in a multi-player version) to SL in order to support software engineering teaching, while Yap (2011a) had recreated an instructional maze in a simulation of a gigantic computer to teach computer hardware. Terzidou et al. (2012) report on the game "Grafica" where students collaboratively play a hunting game aiming at multimedia learning. Finally, Delwiche (2006) used SL as an environment where students created their own games.

Interaction via simulations is another activity, where students have to enter a maze and use previous knowledge to find the exit (Wuesijana et al. 2007), or collaboratively make decisions for a network typology design in a Telecommunication Lab (Goel et al. 2012). Ryoo et al. (2009) designed a role playing learning task to teach information security skills. Polack-Wahl (2009) investigated the possibilities of SL in a data visualization course, by presenting visualized transportation and demographic data.

Finally, SL was used as a medium to deliver online courses and hold lectures or course sessions (Gonzalez 2007; Cliburn and Gross 2009; Thomassen and Rive 2010; Ritzema and Harris 2008; Esteves et al. 2008, 2011; Wei et al. 2009; Hemmi et al. 2009; Laws et al. 2009; De Lucia et al. 2009; Zhang et al. 2010; Herold 2010; Lester and King 2009; Ensslin and Slocombe 2012; Griol et al. 2012; Lim and Kim 2015) and tutorial meetings (Hansen et al. 2008; Good et al. 2008; Loureiro and Bettencourt 2014; Da Silva et al. 2011; Da Silva and Garcia 2013).

4.2 L2 language learning & linguistic studies

The majority of the 40 studies concern English, Spanish or Chinese teaching as a foreign language (L2). They mainly use communication inside the MUVE.

Liang (2012a, 2012b) used SL as part of an English course with students participating in conversations through chatting or engagement in role play games. Peterson (2010, 2012) also investigated synchronous chat interactions to study English language learning by having his students present topics to their peer-audience. Virtual tours followed by discussions were also performed in teaching Spanish (Jauregi et al. 2011; Canto et al. 2013), Turkish (Balcikanli 2012), and English as a foreign language (Liou

2012; Liou and Wang 2012). Similarly, Wehner et al. (2011) combined virtual tours in Hispanic locations with presentations performed by students. In Bolldén 2015, Bolldén conducted lectures in a simulated classroom setting for English teaching.

Deutschmann and Panichi (2009), Deutschmann et al. (2009), Petrakou (2010), Wang et al. (2009), Wang et al. (2012) as well as Zhang (2013) have reported on meaningful and collaborative learning activities that were performed between native and foreign English language speakers. The activities involved lectures, workshops, discussions, virtual tours in groups and individual presentations. Antoniadou (2011), Dooly (2011), Dooly and Sadler (2013) have enriched the above types of collaborative activities with a scavenger hunt in SL.

Another approach to L2 is the simulated scenarios inside the SL. Henderson et al. (2010) had students negotiate on food choices in a virtual Chinese Inn. Lin et al. (2014) developed three virtual places to pair friends, discuss a Family Day and escape from a maze respectively. Simulated places such as supermarkets and banks were developed and enriched by role playing activities by Milton et al. (2012), Pasfield-Neofitou and Huang (2015), Hsiao et al. (2015). Role playing activities on an existing island were also proposed by Jamaludin et al. (2007), Jamaludin et al. (2009), Ho et al. (2009) as well as Cheng et al. (2010). Kim and Blankeship (2013) had their students prepare and conduct lessons to teach Chinese to foreign language learners. Ibáñez et al. (2013) simulated a place where students had to read and communicate with bots or collaborate for L2 English learning.

Content presentation and delivery through simulated places is a slightly different approach to L2 teaching. Chung (2011, 2012) combined 3D objects with their English word for vocabulary acquisition in a virtual restaurant, street, school and a cafeteria. Rogerson-Revell et al. (2012) presented relevant information in simulated classrooms, while Lan et al. (2015) designed a kitchen, a supermarket and a zoo and introduced icons of written words in Mandarin Chinese. A role playing game was presented in one study regarding Chinese as a foreign language (Zheng 2012).

Building and collaborative activities in an architectural context were presented by Wigham and Chanier (2013, 2015) to teach English as a foreign language. Building combined with role playing activities was presented by Sanchez (2007), while Mayrath et al. (2011) focused on the enhancement of English writing skills.

4.3 Healthcare

The majority of the 29 studies on Healthcare are simulations for the diagnosis, assessment or treatment and concern interns. Schwaab et al. (2011), aiming to prepare medicine students for their oral emergency examinations, simulated an emergency room where students had to examine a virtual patient. Honey et al. (2012) replicated a real clinical setting, where the patient lies on a bed and the student-nurse has to respond accordingly. In both studies, the patient acts as the proctor and helps if necessary. Savin-Baden et al. (2011), Beaumont et al. (2012), and De Jong et al. (2014) have developed an avatar-driven scenario for paramedic cases which involved a motorcycle accident with a bot-patient. Antoniou et al. (2014) have developed a periodontology case scenario that applies student knowledge.

Another type of simulation concerns surgical training. Patel et al. (2012) aimed to improve novices' management skills by delivering a course where students were familiarized with a virtual operating room. Beyer-Berjot et al. (2014a, b) and Beyer-Berjot et al. (2015) presented four cases for preoperative assessment through role playing.

Simulations were also used for delivering content related to specific healthcare topics. Ahmad et al. (2010), Ahmad et al. (2011) used tutorials, simulations and quizzes. Jin (2011) had bots send teaching content to students on disease control. A laboratory with anatomical information was created by Richardson et al. (2011). Chow et al. (2012) have presented material to shape nurses' professional conduct in "rapid sequence intubation" situations. Cook (2012) reported on a simulation of examination rooms where nurse practitioners could gather information from the patient, the parents, a computer and medical tools. A different use of SL has been recorded by Maderuelo et al. (2014) who developed a virtual laboratory to teach facility and safety issues. Chodos et al. (2014) had their emergency medical technician students rescue a car-crash victim and hand him off to hospital personnel.

A number of studies have focused on enhancing students' competency in communication skills. Warland and Smith (2012) and Warland et al. (2012) explored the use of a role playing activity to equip midwifery students with communication skills. Sweigart et al. (2014) developed a variety of virtual psychiatric clinical cases where students interviewed the patients. In addition, some studies presented simulated clinical scenarios for midwifery students in a collaborative, (Rogers 2011; Caylor et al. 2015) or individual setting (Peck and Miller 2010; McCallum et al. 2011).

Four studies present the organization of virtual congresses and symposia. Wiecha et al. (2010) delivered a lecture to physician students on insulin therapy and introduced two mock diabetes patients at the same time. Hermanns and Kilmon (2011) designed an alternative space for holding a mental health clinical conference. Benito et al. (2013) organized a virtual scientific congress for their students to present their assignments. Schoonheim et al. (2014) and Codier, Neves and Morrison (2014) focused on distance learning and delivered a virtual session in SL to address the needs of an international online course.

Finally, SL was used as a tool for experimentation to gather useful information in health-related places through virtual tours (Tiffany and Hoglund 2014, 2016).

4.4 Pedagogics

The main focus of 23 studies was the educational process itself.

Place exploration was used in order for educators to investigate the potential of SL in teaching (Dickey 2010) and in multicultural literacy (Aldosemani and Shepherd 2014).

Communication and role playing activities were two other cases. Gao et al. (2009) had their students perform role-playing activities both face-to-face and in SL. Traphagan et al. (2010) compared SL and TeachNet by using argumentation activities among students. Bulu (2012) motivated students to participate in small-group role-playing activities, discussions and meetings in a course on teaching methods. Role-plays based on de Bono's "Six Thinking Hats" were performed by students (Gregory and Masters 2012). Vasileiou and Paraskeva (2010) taught role-playing to teachers by involving their students in a scenario from Homer's Odyssey. Puvirajah and Calandra (2015) had their students role-play in a virtual parent-teacher conference in order to teach classroom management. Dooley et al. (2014) also conducted role playing activities where students reenacted scenes from books and took virtual trips to museums.

Classroom representation was created in order to enhance students' ability and self-confidence in real practice teaching (internship). Mahon et al. (2010) motivated students to teach in virtual classroom-settings composed of student-bots and peer-avatars. Cheong (2010) focused on students' development of teaching efficacy and designed teaching practice and reflection activities in a replica of a school and classrooms. Alotaibi and Dimitrov (2013) designed a place where trainee teachers could acquire some practice on virtual face-to-face teaching. Students were either real observers or smartbots. The SLOODLE tool was also used. Okita et al. (2013) focused on recursive feedback provided to tutors observing their students teaching. Muir et al. (2013) also designed a typical upper-primary classroom where students held lectures on teaching practices. Furthermore, Ma et al. (2014) examined the implementation of a simulated class setting to prepare prospective teachers to teach algebra to a diverse set of students.

Papachristos et al. (2014) and Hearrington (2010) delivered lectures, as the main activity in SL, on the use of MUVEs in teaching and learning for education students. Virtual sessions were held in different settings, either traditional auditorium simulations or open-air settings. On the same wavelength, Bower et al. (2016) examined the factors that support a blended reality collaborative learning setting and held lectures as well as collaborative discussions among students gathered in two different spaces. Burgess et al. (2010) lead two virtual sessions with communication activities for a course on instructional technology.

Finally, Wilks and Jacka (2013) examined the implementation of SL in teaching and learning Visual Arts and conducted virtual meetings and discussions with artists, organized visits to a virtual Sistine Chapel as well as created activities that displayed students' work in an art gallery.

4.5 Science studies

The majority of the interventions in sciences (15 studies) concern simulations. Cobb et al. (2009) developed a virtual bioscience lab to enhance students' understanding of Polymerase Chain Reaction, while Clark (2009) reported on a "Genome Island" virtual lab. Abbas (2010) aiming to enhance learning experiences designed a simulation regarding "Process Dynamics and Control" in a Chemical and Biomolecular Engineering course. A virtual experiment was also designed by Vrellis et al. (2010) to examine a collaborative problem-based physics activity. Eckelman et al. (2011) had their students experience field trips with a simulated virtual pulp and paper mill in order to teach industrial ecology and environmental management. Students were also involved in simulation creation by having to configure a terrain to build a drainage basin (Hung et al. 2012). Aydogan et al. (2010) designed a hydroelectricity power plant and Aydogan et al. (2014) a power transformer (2014). In both studies, authors conducted field trips with their students in these environments. Students also took part in field trips thanks to the simulated environment of the lake Koronia in Greece in order to discuss natural resource sharing (Barbalios et al. 2012).

Gaming inside SL was used by Ye et al. (2007a) in order to study stream pollution. Cooper et al. (2009) report on the value of educational games in teaching sugar and water solubility, as well as erosion and deposition. Bradley et al. (2009) transferred the web game "Spectral" into SL to teach molecules. Wyss et al. (2014) developed the game "Cotton Island" to teach how to grow and manufacture cotton as well as testing and designing cotton products.

Schendel et al. (2008) utilized SL in order to manage an exhibition of students' work regarding "biomes" and "diversity". Finally, Kanematsu et al. (2014) offered virtual lectures to teach radioactivity.

4.6 Business and marketing

The 15 studies found include communication among participants in real scenario representations.

In the Dong et al. (2010), students had to play roles in order to operate an online garment store. Role play was also the main activity presented by Rudra et al. (2011). Students played the roles of vendors and purchasers in an activity related to enterprise resource planning software solutions. Drake-Bridges et al. (2011) used SL for the design of an expo with retail and wholesale shells where students could play the role of either product developers or retail-buyers. Ward et al. (2015) aiming to increase the awareness of entrepreneurialism, gave roles to students to enact in a Dragon's Den, a supermarket and a counseling agency.

Field trips were used by Dreher et al. (2009a, 2009b) where students attended lectures, participated in meetings and developed business systems. Mathews et al. (2012) report on field trips where students investigated product promotion and brand practices. Schiller (2009), Schiller et al. (2013) also report on the exploration and observation of marketing activities through field trips.

In order to prepare students to collaborate effectively in a changing work world, Carmichael et al. (2010) and Carmichael (2011) motivated their students to work in groups and complete assignments related to a scavenger hunt. Noteborn et al. (2014) also assigned students to collaborate and develop, promote and sell products in SL. Schouten et al. (2016) encouraged their students to collaboratively make decisions on the development plan of a vacant space in a virtual neighborhood.

Meetings were organized by Mennecke et al. (2011) aiming to teach the nature of the purchasing process. Students in SL organized meetings and presented posters to stakeholders and participants of an event (Sutcliffe and Alrayes 2012).

Halvorson et al. (2011) studied the use of SL in teaching two marketing classes by organizing lectures in the virtual world.

Bianchi et al. (2015) assigned students to experience a real working environment through the virtual enterprise of the University.

4.7 Design & architecture

Eight empirical studies in the field of architecture & design were found.

Field trips and communication activities among students, architects, educators and non-academic participants on the design of virtual urban housing plans have been reported by Jarmon et al. (2008) and Jarmon et al. (2009).

In the study of Gard and McAuliffe (2009) students were assigned to collaboratively build a virtual landscape in SL. Hollander and Thomas (2009) and Thomas and Hollander (2010) used SL as an active sandbox to teach physical planning and design.

D'Souza et al. (2011) aiming to teach spatial, kinesthetic, logical and verbal and interpersonal/intrapersonal skills, asked their students to participate in a project where a zoo had to be built.

Furthermore, undergraduate students from an "Interior Design" course were asked to navigate a building in order to explore the use of SL as a spatial learning tool (Memikoğlu 2014).

Finally, Le et al. (2015) proposed a series of role play scenarios to teach construction safety. Students in an internship context had to use the information presented in SL, discuss solutions to an accident case study and inspect a building for hazards as they would do in a real life scenario.

4.8 Library & information science

The five studies of Library and Information Science concern mainly lectures. Holmberg and Huvila (2007) aiming to explore the use of SL in distance education, designed a virtual representation of real classrooms and auditoriums, and organized a lecture for working librarians. Similarly, Davis and Smith (2009) conducted a series of lectures for two courses: Digital Africans and English Composition.

The San Jose State University School of Library and Information Science experimented with a number of projects in SL in order to establish a virtual environment for distance learners (Haycock and Kemp 2008).

Rodrigues and Sedo (2008) studied the teaching of information literacy through lectures, meetings, and a scavenger hunt.

Finally, a large set of activities have been conducted by using SL for discussion meetings, lectures, library conferences and tours (Webber and Nahl 2011). Students' assignments consisted of interviews, presentations, exhibitions and teaching designs in SL.

4.9 Engineering

In engineering, students held online meetings to collaboratively solve scheduling and management problems for business projects (Keskitalo et al. 2011). Students also attended lectures about electronics (Beltrán Sierra et al. 2012) and Aerospace Design (Okutsu et al. 2013) or participated in learning activities provided in an engineering lab (August et al. 2016).

4.10 Hospitality & tourism

Only three studies were found on Tourism and Hospitality Management education. SL was used for field trips to familiarize students on becoming tour leaders (Hsu 2012). It was also used for lectures, role play and guest room design activities (Penfold 2008), as well as for a scavenger hunt (Huang et al. 2016).

4.11 Social sciences

In the field of Social Sciences, Procter (2012) in a study on identity issues, asked students to make their own avatars, modify their appearance and buy things from virtual malls. In addition, Wilson et al. (2013) described an initiative concerning the simulation of a home visit in order to instruct social worker students direct practicing skills. Reinsmith-Jones et al. (2015) used four simulation settings, a village, a plane crash site, a store and the holocaust virtual museum to teach students social welfare and work issues.

4.12 Other disciplines

The review revealed only a few studies regarding disciplines different from those presented above.

In Mathematics, Murad et al. (2011) designed a place in SL where students could gain a better understanding of designing 2D models which represent 3D objects. Shipulina et al. (2012) and Shipulina et al. (2013) designed a simulated setting consisting of a pond with shallow water. The task for high school students was to find the shortest route among two platforms.

In Archaeology, Salmon et al. (2010) encouraged their students to visit places in order to resolve their learning challenges on space/landscape. Getchell et al. (2010) encouraged their students to acquire knowledge on excavations by conducting a field trip in a virtual archaeological site concerning a Byzantine Basilica church.

In theater studies and film production, students were tasked to reconstruct a virtual scene from the film "Battleship Potemkin" (Foss 2009). Moreover, the implementation of SL concerned field trips in virtual recreations of historical theaters such as the Caledon Gaiety Theatre and Epidavros (Kuksa and Childs 2010).

In Photography, students used SL tools to practice digital photo taking (Salmon et al. 2010), or attended lectures and exhibited their photos (Doyle 2010).

In Psychology there is only one study regarding a role playing activity where students played the roles of case managers or clients in order to communicate with the members of a military family with various problems (Levine and Adams 2013).

Ellison and Matthews (2010) aiming to teach History via social networking systems, used SL for students to develop the virtual reconstruction of 18^{th} century London.

Concerning Law studies, Nesson and Nesson (2008) delivered videotaped lecture content and conducted meetings among students and their professor.

Chang et al. (2012) aiming to support students in career selection, designed a setting in SL where interviews were conducted among students from three departments.

Yap (2011a, 2011b, 2011c) reported on two simulations that are not possible to revisit in reality, a cybercrime and a toxic gas case.

Cao et al. (2014) have created a simulation of environmental places to teach functional apparel design.

Finally, Corder and U-Mackey (2016) aiming to develop students' intercultural competence, arranged virtual meetings and discussions among students with topics related to socialization and identity.

Summarizing the activities, Table 2 presents the learning activities of the axial coding process, while Fig. 1 presents the activities according to the selective coding process.

Table 2 Learning activities at the axial coding level

Learning activities	Disciplines								
	Computer Science	L2 Language learning & Linguistic Studies	Healthcare	Pedagogics	Science Studies	Business and Marketing	Design - Architecture	Library & Information Science	All Disciplines
Building	5	4	0	2	1	4	2	1	22
Scripting	10	0	0	0	0	0	0	0	10
Multimedia design	2	0	0	0	0	0	0	0	4
Environment design	3	0	0	0	1	0	4	0	9
Interaction with content	5	2	3	0	0	0	0	0	11
Interaction with simulated environments	2	4	2	1	3	0	0	0	12
Exploration of concepts through visualizations/ modeling	1	0	0	0	3	0	0	0	5
Place exploration	2	7	3	4	2	3	4	2	32
Tutorial session delivery & attendance	19	7	6	4	1	3	0	5	49
Communication	3	13	1	6	1	0	2	1	27
Interviewing	0	0	0	0	0	0	0	0	1
Collaboration & Cooperation	12	8	2	1	0	3	2	0	28
Role playing	1	10	7	7	0	0	0	0	30
Game play	5	3	2	0	4	1	0	0	16
Game creation	1	0	0	0	0	0	0	0	1
Virtual internship	0	0	9	6	0	6	1	0	23
Communication/ collaboration with companies	0	0	0	0	0	0	0	1	1
Virtual participation in social events & actions	0	6	0	0	0	0	1	0	10

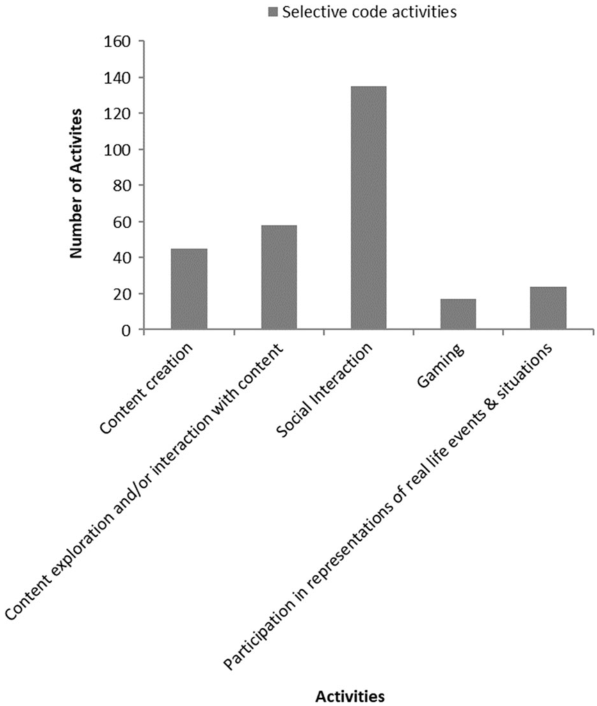

Fig. 1 Learning activities at the axial coding level for all disciplines

The association of learning affordances with learning activities is done by taking into account the more abstract category of activities, namely selective coding. Thus, the learning affordances that are the intended actions permitted by a certain environment are associated with the integrated and refined categories (Wolfswinkel et al. 2013) of learning activities (Table 3).

5 Conclusions

This work proposes a new classification of learning affordances of "sandbox" type MUVE platforms, like Second Life, as well as a new set of learning activities, classified from a lower to a higher level, that may develop in MUVEs. These learning activities are based on a literature review of relevant empirical studies and are well associated with the proposed learning affordances. They are free navigation, creation, modeling and simulation, multichannel communication, collaboration and cooperation, and content presentation and/or delivery.

The learning activities found corroborate the activities proposed by Inman et al. (2010) who generalized the ways of utilizing SL and proposed potential uses in education. The learning activities also share many similarities with those found by Dalgarno and Lee (2012). However, the new activities presented in this work are more explicit and are classified in three hierarchical levels in order to meet the needs of instructional design in MUVEs and justify their characterization as “learning” activities. The selective coding categories formed namely content creation, content

Table 3 Selective coding activities and their associated learning affordances

Selective categories of learning activities	Learning Affordances
Content creation	Creation Modeling and Simulation
Content exploration/interaction with content	Free navigation Content presentation and delivery
Social interaction	Multichannel communication Collaboration and Cooperation
Gaming	Content presentation and delivery Multichannel communication Collaboration and Cooperation
Participation in representations of real life events/situation	Creation Modeling and Simulation Free navigation Content presentation and delivery Multichannel communication Collaboration and Cooperation

exploration and/or interaction with content, social interaction, gaming and representation of real life events and/or situations can be easily assigned to the learning affordances of MUVEs. The activities of the axial coding (Table 1) may guide teachers to relate theory and practice and therefore design meaningful learning tasks in MUVEs. The learning activities in the open coding level can be regarded as examples implemented in MUVEs. This means that the specific learning activities designed in MUVEs might continuously enrich the open coding category. The selective coding activities remain fixed and form a general category of activities.

Table 1 also shows a top – down hierarchy. As the selective coding category decreases, the activities in both axial and open coding become more complicated and authentic. For example, building an object can be characterized as a basic activity, while a virtual internship is close to a real life situation.

Our results show that empirical studies have been conducted mostly in computer science, L2 language learning & linguistic studies, healthcare sciences, pedagogics, business & marketing and sciences. Less than ten studies were recorded in design & architecture, library information science, engineering, hospitality & tourism, and social sciences. Two or three studies were found in mathematics, archaeology, art, psychology, history, law and photography. These results are in line with the review presented by Wang and Burton (2012). However, they are different to those found by Salt et al. (2008), Fang and Lee (2009) and Inman et al. (2010). This difference is rather expected since the number of relevant published work starts rising from 2009. The healthcare and sciences fields were not previously recorded. It is also noted that the previous literature reviews report conceptual discussions, reviews and content analyses in addition to empirical studies.

In the aforementioned disciplines, the learning activities mostly refer to student-centered models as reported by Inman et al. (2010) and Wang and Burton (2012). The student-centered activities we found refer to content creation, content exploration & interaction with content, social interaction (excluding tutorial session attendance), gaming and participation in representations of real life events & situations. Concerning content creation, the reviewed studies reveal numerous assigned activities: building, scripting as well as multimedia and environment design. Scripting was used mostly in computer science studies where programming is among the teaching subjects. Building and environment design was often used in design & architecture, as expected. It seems that building and environment design is considered to be an easy to implement activity, since it is also relevant to other disciplines where it is not the main purpose. Place exploration was also often used, as an easy activity.

Social interaction was found to be the main activity performed in humanities and social sciences, as expected. Many of the reviewed articles concern L2 language learning & linguistic studies which agree with the review published by Aydin (2013). Social interaction was also recorded in many articles regarding pedagogics, confirming the results of Jabbari et al. (2015).

Although gaming is reported in a number of studies regarding various disciplines, the only case of game creation is recorded in computer science (Delwiche 2006). This is probably because game development is a really difficult activity.

Representation of real life scenarios is another activity often used. In some disciplines such as L2 language learning and linguistic studies, healthcare, pedagogics and business & marketing, students are involved in realistic case studies in order to develop their competency as professionals.

Concerning teacher-centered activities, tutorial session attendance is the only activity recorded. It was used in library information science, hospitality and tourism as well as engineering.

The learning activities found and presented from a certain level of abstraction through the selective coding process, empirically confirm the proposed six learning affordances of MUVEs presented in this paper. Our findings indicate that multichannel communication as well as collaboration & cooperation were mostly utilized (26% each). Content presentation & delivery was used in 15% of the studies and free navigation in 13% of the 205 articles. Finally, creation and modeling and simulation had an average of 10% each.

The association between learning affordances and activities contributes to both educational research and practice. An educational researcher may design a MUVE for educational purposes by following learning affordances. A teacher may use this properly designed MUVE in order to develop their learning activities.

This study, despite its large sample, has some limitations that could lead to future work. The review refers only to empirical studies conducted in mainstream education in only one MUVE platform, Second Life, not including MUVEs built with specific affordances in mind. We do believe that the theoretical framework of learning affordances associated with learning activities proposed applies to all "sandbox" type MUVE platforms. However, further research is needed on other MUVEs to establish this framework.

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