Mobile and ubiquitous learning in higher education settings. A systematic review of empirical studies

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Abstract

Mobile and ubiquitous learning are increasingly attracting academic and public interest, especially in relation to their application in higher education settings.

The systematic analysis of 36 empirical papers supports the view that knowledge gains from instructionist learning designs are facilitated by distributed and more frequent learning activities enabled by push mechanisms. They also lend themselves to the activation of learners during classroom lectures. In addition, and as a particular advantage of mobile technology, "hybrid" designs, where learners create multimodal representations outside the classroom and then discussed their substantiated experiences with peers and educators, helped to connect learning in formal and more informal and personalized learning environments.

Generally, empirical evidence that would favour the broad application of mobile and ubiquitous learning in higher education settings is limited and because mobile learning projects predominantly take instructionist approaches, they are non-transformatory in nature. However, by harnessing the increasing access to digital mobile media, a number of unprecedented educational affordances can be operationalised to enrich and extend more traditional forms of higher education.

Keywords: mobile learning; ubiquitous learning; higher education; systematic review

Introduction

Like no previous technology, mobile technology has spread at an unprecedented pace in the last few years. For example, in 2014, the number of mobile phone subscriptions reached six billion (ITU, 2014). Mobile devices are considered cultural tools that are transforming socio-cultural practices and structures in all spheres of life (Pachler et al., 2010). This transformation is considered central even from an evolutionary perspective because it empowers humankind to engage in interactions that are free from the constraints of physical proximity and spatial immobility for the first time (Geser, 2004). Digital mobile devices such as cell phones, PDAs, and smart phones are also being used increasingly often for educational purposes. The educational use of digital mobile technology is at the core of vibrant and expanding streams of research known as mobile and ubiquitous learning. Both concepts are strongly interconnected. While some authors describe ubiquitous learning as a next-generation form of mobile learning where technology fades more into the background (Park, 2011), the terms are often used interchangeably (Hwang and Tsai, 2011). In essence, both approaches strongly emphasise the notion of 'context' in learning. The field of mobile learning conceives the crossing of contexts as one of its constitutional characteristics (Pimmer, 2016). For example, in one the most widely accepted definitions, Sharples et al. (2007) define mobile learning as "*the processes of coming to know through conversations across multiple contexts among people and personal interactive technologies*". Similarly, in ubiquitous learning studies, mobile and portable technologies are conceived either as tools that allow learners to access information irrespective of their physical context, for example on a bus (Chen et al., 2008)or, alternatively, as a way to provide learners with location-based information, for example while they are exploring a butterfly garden (Liu and Hwang, 2010).

To ground the present research on prior literature, the two underlying tenets are briefly and selectively introduced in the next sections: findings from prior mobile and ubiquitous learning studies, and, more broadly, the role of digital media in higher education settings.

Findings and limitations of previous reviews

To date, the educational qualities of mobile and ubiquitous learning have been examined in a number of settings: in formal education settings in and outside the classroom (e.g. Frohberg et al., 2009), in the workplace (e.g., Pimmer and Pachler, 2014), and in the context of lifelong learning (e.g., Sharples, 2000). Regarding higher education, some authors expect mobile learning to radically transform this field by providing *"new strategies, practices, tools, applications, and resources to realise the promise of ubiquitous, pervasive, personal, and connected learning"* (Wagner, 2005). Two recent meta studies provide an overview of and insights into the emerging socio-technical phenomenon (Hwang and Tsai, 2011, Wu et al., 2012). Wu and colleagues (2012) found in their meta-analysis that research has most commonly concentrated on the effects of mobile learning, followed by design aspects, the investigation of the affective domain during mobile learning and the analysis of learners' characteristics. Regarding the course subjects, mobile learning was studied primarily in the setting of language and linguistics courses, followed by computer classes and health sciences (Wu et al., 2012). The authors also noted the predominance of higher education settings among mobile learning environments; more than half of the learners included in the meta-analysis were from post-secondary education environments (Wu et al., 2012). Similarly, Hwang and Tsai (2011) reported that higher education students were the most often researched target group for mobile learning studies. Notably, in both meta-analyses, most of the included studies reported positive learning outcomes.

In these reviews, relatively little attention was paid to the different forms, practices and outcomes of mobile learning and their theoretical underpinnings. For example, in the instructionist sense of learning, mobile devices can be used to test vocabulary (Brett, 2011), while a constructionist approach might have students use

mobile devices to create video materials (Zahn et al., 2013). While both uses could be labelled “mobile learning”, the associated learning activities and underlying theories are diverse and are likely to result in different forms of engagement and educational effects. One of the first reviews that differentiated mobile learning on the basis of different theoretical strands was written by Naismith et al. (2004). They distinguished behaviourist, constructivist, situated, collaborative, informal and lifelong learning categories. Their review, however, was based on examples and was not systematic. Another literature analysis was conducted by Frohberg et al. (2009). In their critical review of mobile learning projects, the authors used activity theory (Engeström, 1987, Sharples et al., 2007) as an analytical framework. They analysed more than 100 projects according to the categories *context*, *tools*, *control*, *communication*, *subject* and *objective*. Frohberg et al. (2009) observed that although mobile phones are primarily communication devices, communication and social interaction played a surprisingly small role in mobile learning projects. However, the reviewers did not focus on higher education settings, and more importantly, their review included projects that were published before the end of 2007. As noted in subsequent systematic reviews, the number of mobile learning studies increased sharply after this period (Wu et al., 2012, Hwang and Tsai, 2011). In the more recent analysis of mobile lifelong learning projects, Arrigo et al. (2013) also suggest that most of the projects were centred on the distribution of content instead of on social interaction between tutors, teachers or peers using mobile devices.

Educational technology in higher education

More generally, the use and role of digital technology in higher education is contested. Its transformational potential has been frequently stressed by some scholars, especially if online learning is blended with face-to-face teaching. Garrison and Kanuka (2004) argue, for example, that these formats have started to question the "*dominance of the lecture in favor of more active and meaningful learning activities and tasks*" (p. 100). Specific reviews, for example from the field of health professions, reveal moderately positive results to date. Although internet-based education formats are associated with large positive effects compared with no interventions, they show a similar effectiveness when compared with traditional non-internet-based teaching (Cook et al., 2008a). Beyond the outcomes of specific interventions, authors who consider the "bigger picture" of higher education are more critical. It is argued that, despite the abundance of digital technologies, the usage of new technologies in higher education is sporadic, uneven and rigid (Selwyn, 2007) and concentrates on the content-driven reproduction of behaviourist educational patterns (Blin and Munro, 2008). This is reflected in Cuban et al.'s (2001) study, in which they observed that access to digital technology did not lead to its widespread use; and, when used, computers sustained rather than changed existing teaching practice. They explain this tendency with a lack of time and ICT training on the teachers' part (2001). In addition to teachers, students are also affected by constraints in the use of online learning in higher education, for example regarding the lack of a sense of community in online environments, difficulties in understanding learning goals and technical problems (Song et al., 2004). Cuban et al. (2001) tie the modest adaptation of digital technology to the concept of a 'slow' revolution, which means that individuals and organisations require decades to learn how to fully use and exploit new technologies. While the observations of Cuban et al. (2001) were made in a high school context, the arguments regarding slow change patterns were also found in higher education settings, with digital technology being gradually adopted over decades in ways that improve existing practices, rather than radically changing them (Kirkup and Kirkwood, 2005).

To conclude this introduction, after more than 20 years of mobile learning research there is still relatively little systematic knowledge available, especially regarding the use of mobile technology in different educational designs and with associated educational effects in higher education settings. Of interest is also the question whether, and if so, how a technology marked by many as "revolutionary" can impact on established learning and teaching in a context which appears to be resistant to change.

Materials and methods

Research question and goal

This review intends to address the following broadly focused research question: How can mobile ubiquitous learning formats in higher education be synthesised according to their theoretical underpinnings and to what extent are these categories tied to different educational outcomes? Addressing these questions is expected to result in a more nuanced and theoretically grounded understanding of the pedagogical effects of different mobile learning arrangements.

Search strategies and techniques

The overall procedure followed the steps that Cook and West (2012) suggested for conducting systematic reviews. First, the research questions, as stated above was defined; this was followed by protocol writing, the search for eligible studies, decisions about inclusion/exclusion criteria, the review of title abstracts, and the actual analysis. Finally, the synthesis was written up. Mobile and ubiquitous learning activities can be highly diverse, offering different educational qualities and depending on and interacting with complex social systems and contextual influences. Thus, an in-depth understanding of this emerging phenomenon requires not just the consideration of quantitative studies, but the pooling of selected quantitative, qualitative and mixed-method study designs. This selection process should also allow a consideration of the nuanced theoretical understandings of the different studies and the elicitation of relationships across the selected works. Accordingly, the selected qualitative synthesis methodology approach was thematic analysis, which includes the analysis and interpretation of texts and refining the findings into key 'themes' (Bearman and Dawson, 2013). The approach was integrative, in that the literature was grouped according to pre-existing educational designs(s); it was also interpretative, in that those designs were further developed, and key themes were identified within these categories (Bearman and Dawson, 2013). The themes were identified and developed via iteratively reading, re-reading and interpreting the text, as outlined below.

To identify relevant high-quality papers, the first wave of searches involved identifying publicly available and peer-reviewed articles in the Web of Science databases. The search was conducted in August 2013 and included contributions in English from 2000-2013. The search terms combined the concepts of mobile and ubiquitous learning and higher education in the meta field "topic", which included the search in article titles, abstracts, author keywords, keywords and plus fields. More precisely, the terms *mobile learning*, *m-learning* and *ubiquitous learning* were combined (AND) with *higher education* or *university* or *post-secondary* or *post-compulsory*. The search yielded 175 results. In addition, the database ERIC was searched in September 2013 because this source contains a broad selection of articles specific to the fields of education and learning sciences. The search was based on the same combination of concepts and search terms and yielded another 176 publications. The third wave of searches comprised scans of Google scholar using the same key terms.

Selection process and inclusion and exclusion criteria

After deleting 56 duplicates, the first author conducted a review of 295 publications' abstracts. Of this body, 194 studies were deleted because they did not meet the inclusion criteria. For the remaining 101 publications, the full texts were retrieved and reviewed against the following six criteria: (1) sound methodological design; (2) higher education setting; (3) involvement of mobile technology; (4) educational orientation; (5) primary study designs based on mobile learning activities:

First, a study needed to include **sound qualitative, quantitative or mixed method research** designs. Studies of lower methodological quality were not considered. That is, qualitative studies needed to both describe their data-gathering procedures (techniques, participant numbers, and recording/transcription) and indicate their

analytical techniques (e.g., grounded theory and constant comparison analysis). Regarding quantitative designs, exclusively descriptive studies were not included. The studies needed to describe study population (e.g. number of participants, gender, etc.), intervention and (experimental) procedure, and all necessary information regarding the statistical tests used (e.g. mean and standard deviation for parametric tests, etc.). For mixed-method studies, at least the qualitative or quantitative requirements needed to be met for the respective results to be included.

Second, the target group needed to consist of students from higher education settings. Such learning settings included lectures, excursions, museums, field visits or placements that were part of higher education programs. Third, the studies needed to investigate the use of digital mobile technology, including such devices as mobile phones, PDAs, tablets and mp3 players. Excluded were less-portable devices such as laptop or desktop computers because the application of these devices has been analysed and discussed broadly in the 1:1 computing literate (e.g., Bebell & Kay, 2010). Fourth, to be considered, the studies needed to have a clear orientation towards education. This included studies with a primary focus on learning that involved teacher-centred, self-directed and informal forms of learning. Studies were excluded if they centred on arrangements that were not directly related to educational activities, such as the design of mobile library services. Fifth, the studies needed to be based on the collection and analysis of primary data about mobile and ubiquitous learning activities. Studies were excluded if they (a) were theoretical and conceptual papers without an empirical basis; (b) described only the design of a system without evaluating usage and learning patterns; (c) analysed students' general perception of mobile and ubiquitous learning without referring to or describing any specific activity or didactical setting; and (d) focused on the future or intended use of mobile devices, e.g., Delphi studies.

Data coding and analysis

Based on the criteria, 36 studies were identified as eligible for the review and were comprehensively analysed by two of the authors. The analytical process included the reading, re-reading and analysis of the papers according to the following parameters: The main analytical parameter was the educational design and the underlying theoretical orientation. The analysis for this category was applied in a semi-grounded way: The investigation started with a synthesis of categories from previous research, specifically the categories proposed by Laurillard (2009) and Naismith et al. (2004): *instructionist*, *constructionist*, *situated and collaborative designs*. During the analysis, the nature of the studies suggested merging the constructionist and collaborative categories and considering the emerging category of hybrid designs. It should be noted that these categories are very broad theoretical strands and that the analysis could not do justice to the different, historically developed nuances and detailed interpretations of those categories. However, the analytical system was a viable tool for considering and analysing the different educational designs and attendant theoretical underpinnings at the core of the identified studies. The second main criterion concerned the effects of the intervention. These were analysed according to three dimensions: (a) learning outcomes, i.e., the self-reported or measured changes in skills, knowledge or attitudes associated with a learning programme/activity; (b) satisfaction, i.e., the learners' acceptance of and reaction to a mobile learning activity; and (c) usage, i.e., the frequency, intensity and/or quality of the learners' engagement. The last aspect is an important complementary indicator because mobile learning activities that are highly rated but rarely used by learners would have only limited effects. The reported effects were extracted and qualitatively and quantitatively described (see also Appendix), and the results are synthesised in the results section. In addition, the following parameters were used to classify the identified publications: the subject of the course (e.g., computer science) and the country from which the study originated. Regarding the subjects, the sub-disciplines of the classification that Wu et al. (2012) used in their m-learning review were applied. For this classification, the themes of the individual courses were extracted; e.g., if computer science students used their mobile phones to participate in an English class, English (and not computer science) was extracted as the discipline. For the

geographical background, the location of the university was used; e.g., if university students from Germany learned during an excursion in Spain, Germany was extracted as the country.

Regarding the quality of the research design, all the selected studies were reviewed independently by the first and the second author. Differences in the interpretation were resolved upon discussion. The same measures were applied regarding the two main categories (parameters), i.e., the effects of the intervention and the educational design. However, this was an iterative, discursive and, in part, inductive process (involving the generation of a new category, the hybrid design). That mean, although the results represent the agreement of the first and second author, no inter-rater reliability measures were calculated.

Characterisation of the sample

In the 36 examined papers, 47 educational designs were identified. Of those designs, instructionism was by far the most prevalent category: 22 studies in which instructional elements formed a central part of the didactic design were identified. This was followed by constructionist learning (13) and situated action (12). In addition, 6 studies were characterised by a hybrid of situated, constructionist and collaborative designs. From a geographical perspective, the majority of the studies were from the United Kingdom (10), followed by Taiwan (6) and the United States (5). Two studies each were from Australia, Cyprus, Germany, Japan and China. As in the sample of Wu et al. (2012), the three dominant subjects were language learning studies (9), health sciences (7) and computer sciences (6). These subjects were followed by psychology and history, with two studies each.

Results: Pedagogical strategies and outcomes

In the following sections, the usage and outcomes of mobile and ubiquitous learning are synthesised and presented according to the categories of (1) instructionism, (2) situated action and contextual scaffolding, (3) constructionist and collaborative learning and (4) hybrids of situated, constructionist and collaborative designs.

Instructionist education

Instructionism, as characterised by Laurillard (2009) - who is, in turn, referring to Seymour Papert (e.g., 1991) - puts the focus on the *organisation* of instruction and is teacher driven and prescriptive. Instructionism is rooted in the broader psychological concept of behaviourism, which highlights the stimulus-response mechanism. Considering the role of technology, this means using computers to instruct learners or even having computers present the instruction. Instructionism places the presentational and testing capabilities of media in the foreground. In the analysis, three themes were differentiated according to the ways the mobile learning activities were organised:

Ad hoc and post hoc transmission of lectures

The first sub-category is centred on the delivery of lectures, the core format of higher education (Gehlen-Baum and Weinberger, 2014, Apel, 1999, Shen et al., 2009, Solvberg and Rismark, 2012). Generally, the opportunity to participate in live lectures independent of one's location was positively received by students . Using repeated group interviews, Solvberg and Rismark (2012) found that the provision of multimedia-streamed presentations by external lecturers resulted in the creation of new learning spaces: In addition to the classroom, students also gathered in groups at other locations on the campus, where they followed the lecture through smart phones and laptops. Individual learning space involved the post hoc and off-campus study of lectures, which also led to positive attitudes. However, conflicting pressures from family, work and leisure time tended to prevent students from watching entire lectures in one sitting (Solvberg and Rismark, 2012). A similar and also well-received post hoc lecture format was podcasts, which either presented whole lectures (Pearce and Scutter, 2010, McKinney et al., 2009) or summarised key aspects of lectures (Evans, 2008, Lee and Chan,

2007). However, the qualities of mobile devices for podcasting were not convincing: the students tended to listen to the podcasts primarily on laptops and desktop computers at home and used mobile devices to a much lesser extent being on the move (Evans, 2008, Pearce and Scutter, 2010, Lee and Chan, 2007). Using an experimental, non-randomised approach with post-knowledge tests, McKinney et al. (2009) found that students who engaged with audio-synced PowerPoint slides on their own mobile devices in a classroom setting learned significantly more compared with students who watched the traditional lectures. This unexpected result was explained by students who took more extensive notes in the podcast condition and who listened repeatedly to the lectures.

Supplementary text and multimodal materials

Beyond the delivery of lectures, the second category comprises supplementary study materials that were provided to the students' mobile devices using linguistic, audio and visual representations. The use of written language was found to be effective and was well regarded by the learners (Cavus and Ibrahim, 2009, Chen and Hsu, 2008, Thornton and Houser, 2005). For example, SMS messages with medication knowledge were sent twice a day to nursing students who attended a pharmacological lecture. This resulted in significant knowledge gains for the SMS group over time and compared with a control group that did not receive the SMS messages (Chuang and Tsao, 2012). Significant pre-post knowledge gains and high satisfaction rates were also observed in a study in which learners received personalised recommendations and extracted vocabularies for English news articles based on their reading abilities (Chen and Hsu, 2008). Studies also contrasted different mobile and non-mobile delivery formats: Thornton and Houser (2005) showed that students who received vocabulary lessons sent to their mobile phones via email had significantly increased retention rates compared to groups that accessed the same content in a pull format on websites through their mobile phones and PCs in a first experiment and compared with a group that accessed the same content provided on paper in a second experiment.

In addition to the use of written language, studies also examined and contrasted the use and combination of multimodal knowledge representations through pre- and post-knowledge tests. For the retention of English materials, the simultaneous presentation of written and oral language (sound) on smartphones was found to be superior to sound only (Chang et al., 2011). Integrated mobile delivery formats that include text, sound and images were also found to have significantly positive knowledge outcomes for computer science and language learning students: These effects were measured in comparison with control groups who accessed learning content via websites (McPhee et al., 2006, Saran et al., 2012) and via paper based-hand-outs (Saran et al., 2012). Both studies used a quasi-experimental non-randomised pre-post-test design. Comparisons were also conducted with traditional classroom instruction using an experimental between-group post-test design: A group that engaged with English listening, writing, text and image-based information and quiz exercises on mobile devices in a self-paced manner performed significantly better than a group that received synchronous instruction from a teacher using the same exercises; this effect was attributed to the first group's opportunity to repeat learning sequences and check correct answers (Oberg and Daniels, 2013). Regarding the use of moving images, one study demonstrated improvements in practical competences through mobile video instruction, which were evaluated via a post-test only control group design: medical students and residents who studied a stepwise instruction on a PDA performed a chest-tube insertion significantly better than a control group who did not have this support (Davis et al., 2013).

Activation and formative assessment

Beyond the presentation of content, a number of studies focused on analysing how a mobile system could facilitate learning during lectures by posing questions and activating exercises via mobile devices (Shen et al., 2009, Wang et al., 2009, Markett et al., 2006, Gikas and Grant, 2013). Generally, this approach resulted in active participation and engagement during lectures (Wang et al., 2009, Markett et al., 2006) and in high levels

of motivation and satisfaction (Wang et al., 2009, Shen et al., 2009). Students who were reported to be otherwise passive in large classroom settings not only responded to tasks but also expressed self-confidence, praised their instructors, made suggestions, and showed emotions, humour and even disagreement (Wang et al., 2009). The same system was also found to correlate with significantly higher final grades for mobile users compared with non-mobile users (Shen et al., 2009). Interview-based studies also suggest that lecturers appreciated the mobile activation and response systems because they gained immediate feedback from students about their teaching methods and content and received insights into the students' progress (Wang et al., 2009, Markett et al., 2006).

Formative assessment and activation that were initiated outside the lectures yielded mixed results with respect to learning outcomes, attitudes and usage: De-Marcos et al. (2010) reported a study in which students used their mobile phones to answer multiple choice questions tailored to the learning objectives of the course and found that the students had positive attitudes toward the system. However, the comparison of the final marks for the intervention group and the control group (who received the same questions on paper during the lectures) revealed significant results only for the secondary education groups and not for the university-level life sciences students. Using group interviews, log-file analysis and a descriptive survey, Brett (2011) reported less positive findings for a system that provided SMS quiz questions and correct answers for university students: only half of the students engaged with the quizzes. The participants' opinions about the value of SMS learning were similarly split between those who found it valuable to their learning and those who did not and who perceived the use of personal mobile technologies as an intrusion of their privacy. In work-based placements, health and social care students used smartphones to receive formative competence assessments from their supervisors (Coulby et al., 2009), other team members, patients and university tutors in the form of text and voice messages (Taylor et al., 2010). In both studies, the students required considerable support and training in the use of the mobile system. The analysis of the focus groups tied the mobile assessment to an increased level of feedback and found that the learners in the mobile assessment group were more aware of their goals (Coulby et al., 2009) and embedded reflection more regularly in their daily work (Taylor et al., 2010).

Situated action and contextual scaffolding

Situated action focuses on the learners' responsiveness to their environments and the ways in which human action arises in "the flux of real activity" (Nardi, 1996). In terms of educational design, this means facilitating problem solving and inquiry-based learning. Compared to instructionism, situated action learning occurs in a more spontaneous and fluid and much less teacher-guided way in authentic and real-life situations. Instead of controlling and assessing *each behaviour,* learners should be oriented toward the material (Streibel, 1989). In the analysed studies, orientation in poorly structured environments was supported through mobile devices that provided spatial, sequential and cognitive scaffolds according to the specific contexts of the learners. In contrast to "traditional" approaches to technology-enhanced scaffolding (Sharma and Hannafin, 2007), mobile technology provided dynamic scaffolding in complex and messy real-world settings that are not confined by the boundaries of computer screens. One way to achieve scaffolded situatedness was for learners to establish the scaffold, for instance, by accessing knowledge relevant to their needs using pull mechanisms. One example from a qualitative, focus group-based study is the use of PDAs by nurse and medical students during placements to access reference and support tools that facilitate informed decision-making directly at the point of care (Garrett and Jackson, 2006).

Situated learning was also investigated with two groups of biology students who used mobile DVD players on the beach to study static images and dynamic video representations of fish species between snorkelling activities (Pfeiffer et al., 2009). According to the results of this experimental study, the situated learning activities significantly increased the students' ability to recognise fish species, regardless of whether the presentations were dynamic or static. In addition, nearly all of the students found the activity to be helpful or

very helpful for their learning. However, no comparison was made with a "non-situated learning" control group, for example, with learners who studied the same content in traditional settings, such as a classroom. Studies also examined the role of mobile technology in the information-rich settings of museums: Using interviews, Tsai et al. (2011) investigated students' perceptions of mobile learning after they had learned about coins in a museum via contextualised scaffolding messages that were sent to their PDA and adapted to their situation, visit time and prior knowledge. The phenomenographic analysis revealed five categories of conceptions of learning, one of which emphasised the value of mobile technology for offering situated, sequential and cognitive scaffolds, i.e., providing timely guidance and direction in the learning processes. This value was expressed in the statement "*Learners can know what they should pay attention to or what they should do*." (Tsai et al., 2011). Reynolds et al. (2010) observed design students in a similar setting: During a museum visit, the students were guided via paper or PDA-based trails that provided additional information in the form of text, audio and images. The qualitative evaluation showed that the mobile trails served as practical tools that provided orientation in space and as cognitive tools that supported the students' meaning-making and facilitated and intensified their engagement with the museum objects. However, no clear advantages of the PDA over the paper-based trails were identified. On the one hand, the PDA trails were found easier to follow, and the use of audio facilitated active exploration; on the other hand, paper was deemed to be more flexible, better allowing learners to look ahead or to change the order of the trail objects. The students were divided in their evaluation of the scaffolding capacities of mobile devices: some argued that handling the PDA distracted them from engaging with objects, while a similar number found the PDA helpful for structuring the visit (Reynolds et al., 2010) because it provided a sequencing scaffold. Similar observations were made in the randomised experiment of Sung et al. (2010), in which psychology students used a tablet PC-based guidebook to participate in historical role play in a museum and answered history questions related to exhibits. Compared with students who used paper-based worksheets and students who did not receive any materials, the group with the mobile role play spent significantly longer in front of the exhibits. However, no significant differences regarding the conceptual understanding of exhibits were measured (Sung et al., 2010).

Constructionist learning

This paradigm is centred on the notions of construction and co-construction as a process of learning. As coined by Papert and Harel (1991), constructionism emphasises learning by *making* something that *makes sense* in the real life of the learners. This process can involve making "real" objects, such as building a sand castle, or virtual entities, such as programming digital calendars. Constructionist approaches also embrace social learning settings, thus involving co-construction by groups or teams of learners. According to the mobile literature that was reviewed, the multimodal and communication capabilities of mobiles devices support the construction, co-construction and sharing of knowledge in the form of linguistic representations (written and recorded speech) and visual representations (photographs and videos), as detailed in the following sections.

Designing linguistic representations (written and recorded speech)

While the production of lengthy texts with small keyboards can be cumbersome, mobile phones were used and valued for taking quick written notes (Taylor et al., 2010, Schepman et al., 2012). Schepman et al. (2012) implemented a note-taking software. They found that, compared with PC and web users (n=25), students who used mobile devices (n=30) for note taking did not record more notes in total. However, mobile note-takers recorded notes in significantly more locations, and importantly, they created significantly more notes that were labelled ''ideas''. This finding points to the value of mobile technology for capturing and thus better harnessing ephemeral and fleeting ideas. However, the students made little use of notes for reflective practice.

In the literature examined, the value of recording speech to represent meaning to another and to oneself (Cope and Kalantzis, 2009) was perceived inconsistently. In two studies, audio recording for reflective purposes was viewed critically and used minimally by students who were not comfortable talking into their mobile devices (Garrett and Jackson, 2006), particularly in the presence of other people (Schepman et al., 2012). Similarly, initial concerns were also observed in an ethnographic study in which language learners produced voice recordings about personal learning experiences and shared them later in the classroom with teachers and peers. After initial concerns, the learners became used to hearing their own voices and found it easier to speak in front of a machine and not directly to their "authoritative" teachers or the whole class (Ros i Solé et al., 2010). Similarly, language students who audio-recorded their reflections on their academic experiences clearly preferred to use mobile phones rather than a studio because this allowed them to make recordings in familiar environments. The analyses of 400 recordings from 40 students revealed that, compared with the studio production, the "mobile" setting led to a significant increase in language fluency. Students expressed a decreased sense of anxiety when they were able to record their reflections flexibly using mobile devices (Kessler, 2010). Similar to the findings of Schepman et al. (2012), the phenomenological analysis of interviews by Wang et al. (2012) revealed that doctoral nursing students used the audio-recording function of PDAs to document fleeting ideas and thoughts related to their work. This feature allowed them to extend learning and reflection beyond the normal working hours and was aligned with their 24/7 life style and work patterns.

Designing visual representations (photographs and videos)

The construction of visual representations in the form of photographs taken with mobile devices was perceived as a valuable aspect of the learning design in many studies. For example, in a project in which computer science students used audio-recording and camera features to explore information technology in their environments, the camera function became one of the most popular learning activities, and it supported information collection and knowledge construction (Lan et al., 2012). In a setting in which teacher students discussed issues through the exchange of SMS messages and digital pictures taken at training events, a similar observation was made: The semi-grounded analysis of messages and of the group interview revealed that the photo-function of mobile devices was valued for learning and was frequently used (Seppälä and Alamäki, 2003). It was noted that the photographs supported the development of the students' professional identity because they helped the students gain an impression of how they looked in front of a class. The students then used these photographs

to compile teaching portfolios. The use of portfolios to document work experiences was also investigated in the qualitative study by Garrett and Jackson (2006). While busy clinical environments prevented students from creating long e-portfolio entries, they valued the mobile photo function as a viable feature for documenting images as instant reminders. Beyond the creation of still images, Zahn et al. (2013) investigated groups of psychology students who produced videos about obesity stigmatisation with their mobile devices. The quasi-experimental approach showed an increased understanding of the complex subject by the students, who created the videos in small groups. The effects were significant over time and in comparison with the non-equivalent control group, which read a newspaper article on the topic (Zahn et al., 2013).

Hybrids of situated, constructionist and collaborative designs

This category synthesised a number of studies that followed a similar pattern: Firstly, situated and constructionist designs were integrated in informal learning situations outside the classroom. More precisely, this process was initiated through an activity that included the construction of linguistic and/or visual representations (e.g. notes or photographs) through mobile devices in authentic learning environments. This activity made learners scan and reflect on their environments more actively and link their observations with concepts and knowledge from more formal education. Secondly, these personal and "substantiated" learning events were linked with more formal environments, i.e., with real or virtual classrooms. This was enabled through a process that entailed the structured sharing and discussion of the learning experiences with peers and/or tutors in a way that resembles orchestrated collaboration. In essence, studies indicated that hybrid designs facilitated the learners' reconciliation of the different levels of knowledge and experience across formal and informal learning environments.

A number of studies support the observation that “mobile documentation” in authentic environments enhanced “situated awareness” and immediate engagement (Gikas and Grant, 2013, Uzunboylu et al., 2009, Lan et al., 2012, Seppälä and Alamäki, 2003, Hsu and Ching, 2012, Ros i Solé et al., 2010): For example, students in a design course were required to use mobile devices to capture design examples in their daily lives. The content analysis of the students’ tweets and open survey questions illustrated that the assignment to take photographs made the participants aware of course-related themes in their daily lives that they would not have otherwise noticed. As one student noted, the assignment

> *"… made me aware of all of the things that I read about being applied in everyday life. Examples of design that may have gone unnoticed by me were caught"* (Hsu and Ching, 2012).

This learning sequence did not end with the documentation assignment; the students were required to share their experiences with their peers through microblogging and to analyse and comment on their peers’ photographs. In addition to the mutual inspiration and the co-construction of knowledge, the students also reported that the collaborative exercise strengthened the identity of the learning community during this course, which was exclusively held online (Hsu and Ching, 2012). Increased awareness was also reported in the quantitative study by Uzunboylu et al. (2009), in which students took photographs of environmental blights. According to the findings of the pre-post survey design study (n= 41), the students’ attitudes toward the usefulness of mobile learning as a means of improving environmental awareness increased significantly. Again, in addition to the documentation task, the students subsequently discussed their documented learning experiences with peers via chat and suggested solutions for overcoming environmental problems. Furthermore, in the research of Lan et al. (2012), computer science students collected, shared and discussed artefacts (text and images) in authentic settings to solve tasks related to the evaluation of computer hardware and software. The results were eventually presented and discussed in the classroom. The content and sequential analysis revealed that compared with the groups that used web and desktop interfaces, the mobile phone users paid more attention to course topics in their day-to-day experiences and incorporated these experiences into the online discussion. The mobile group engaged more often in reflective practice, shared

more diverse information and achieved higher levels of co-construction of meaning among group members. The authors stated that these differences were explained by the mobile phone features that allow more immediate and situated engagement: the learners did not need to wait until they were in front of a desktop computer to collect, share or discuss their discoveries, and this was interpreted as a motivation for students to more constantly participate in the discussions.

Immediacy was also relevant in the ethnographic study by Ros i Solé et al. (2010), although not in the sense of virtual collaboration: language learners audio-recorded their learning experiences on the spot in authentic and personal spaces, such as when describing a preferred place or conducting interviews with native speakers. These activities led to contextual learning and deep engagement. It was noted, for example, that in a task that involved conversations with native speakers, the learners spontaneously adjusted the themes according to the sensitivity of the audience. Back in the classroom, the learning continued; the learners shared and discussed their documented experiences with peers and lecturers. The students reported that listening to own and other recordings in the classroom made them aware of having a different personality in a foreign language; they referred to having ''a voice I do not normally hear''. This reflective process made the learners revisit both their learning and their self-perception. This reflection was reported to result in the development of self-awareness and positive self-images in the target language (Ros i Solé et al., 2010). Notably, in all of these studies, the collaboration activities that included a discussion of previously substantiated experiences formed an integral and explicit part of the learning script on a macro level (Dillenbourg et al., 2009), i.e., the required collaborative format was pre-structured and sequenced (Hsu and Ching, 2012) and accompanied and closely supported by moderators and lecturers (Uzunboylu et al., 2009, Ros i Solé et al., 2010, Lan et al., 2012).

Discussion and critical analysis

In the following sections, the main findings are synthesised (see also Table 1) and critically discussed, especially in view of the broader use of mobile and ubiquitous learning in higher education.

Categories	Subcategories/ descriptions	Summarized findings
Instructionist	**Ad hoc and post hoc transmission of lectures**, e.g. students listen to podcasts	Positively received, but rarely used by learners on the move via mobile devices; limited evidence for knowledge gains
	Supplementary text and multimodal materials, e.g., text messages with key knowledge messages	Well regarded by learners; significant knowledge/ retention gains compared with no-intervention and non-mobile learning control groups; effects explained by more frequent practice and push mechanisms
	Activation and formative assessment, e.g. mobile response systems during lectures; SMS quiz questions sent on mobile devices outside classroom	Mobile response systems enhanced participation and engagement of learners in lecture hall; formative assessment and activation initiated outside lectures yielded mixed results
Situated	**Situation action and contextual scaffolding**, e.g. learners are provided with context-specific information	Situated instruction helps learners, but no clear advantages of mobile-based over paper-based scaffolding found
Constructionist	**Learners design linguistic and visual representations** (e.g. take photographs with mobile phones)	Inconsistent results: conducive to capturing fleeting ideas, limited evidence for reflective learning; taking photographs was highly valued;
Hybrid	Learners **document learning experience** (notes, photographs) outside the classroom and discuss it then with peers and educators in more formal environments (real or virtual classroom)	Helped learners to reconcile learning from inside and outside the classroom; enabled by more immediate and situated engagement and personalisation of learning

Table 1 Synthesis of learning designs and outcomes

Key messages: The value of mobile technology in higher education

For instructionist approaches, the value of mobile devices can be observed in the facilitation of distributed and more frequent learning and the activation of learners. In contrast to massed delivery, distributed presentation takes advantage of mobile systems' ability to push learning items to students and distribute learning over time. The advantages of distributed delivery for learning and retention have been demonstrated in a number of psychology reviews (see e.g., Cepeda et al., 2006). However, in the studies reviewed, the spacing periods could not be controlled because the students tended to postpone studying the items they received on their mobile devices (Thornton and Houser, 2005). Positive knowledge gains were mainly explained by more frequent practice and repetition as a result of push delivery (Saran et al., 2012, Thornton and Houser, 2005, McKinney et al., 2009, Oberg and Daniels, 2013, Chuang and Tsao, 2012, McPhee et al., 2006). This observation reflects the findings of another systematic review about podcasting that linked significant knowledge gains to situations in which podcast groups were allowed to listen and review material multiple times (Hew and Cheung, 2013). Spacing and repetition effects must be treated with caution in view of scalability. If students are prompted with a great deal of additional content to be studied and are frequently contacted on their private mobile phones outside the classroom, this would likely lead to an additional burden and might be considered as an intrusion of their privacy, as indicated in the study by Brett (2011).

Posing questions and disseminating activating exercises for formative assessment via mobile devices was reported to stimulate and activate learners in the lecture hall (Wang et al., 2009, Markett et al., 2006) and to be positively correlated with final grades (Shen et al., 2009). These observations are strengthened by the findings from reviews about classical audience response systems that facilitate participation and engagement, interaction, and learning performance (Kay and LeSage, 2009b, Kay and LeSage, 2009a). Compared to a few sets of standard voting devices administered by the university, an approach that makes use of the students' growing ownership of mobile devices and the increasing wireless network coverage in classrooms is easier to scale and can thus present logistical advantages.

Regarding the different modalities, the use of multimodal designs in instructionist settings is no prerequisite for the successful implementation of mobile learning; additionally, text-based content was found to produce significant learning gains (Cavus and Ibrahim, 2009, Chen and Hsu, 2008, Thornton and Houser, 2005). However, in line with the dual coding theory and the theory of multimedia learning (e.g., Mayer, 2005, Clark and Paivio, 1991), the integration of audio and text were linked to higher knowledge gains compared with audio only (Chang et al., 2011).

Much of the evidence for the instructionist design of mobile and ubiquitous learning in higher education is grounded in what is known as rote learning and the majority of relevant studies measured the acquisition of simple items, such as vocabulary acquisition (e.g., in 11 language-learning studies). This puts the focus on assessing retention and does not measure higher-level learning goals, such as deeper understanding, sense-making or the application of knowledge to new situations (Mayer, 2002). In other words, rote learning contributes little to powerful higher education environments that focus on generating a thorough understanding among students and on building their sense of identity, as envisioned, for example, by Entwistle and Peterson (2004).

Beyond instructionist affordances, there is some mostly qualitative evidence that mobile devices lend themselves to supporting learners on the move by allowing them to capture ephemeral thoughts, in the form of audio recordings related to work situations (Wang et al., 2012), quick noting of ideas (Taylor et al., 2010, Schepman et al., 2012, Seppälä and Alamäki, 2003) and photographs as instant reminders (Garrett and Jackson, 2006), for later use.

However, the most convincing non-instructionist studies involved hybridisation; that is, integrating situated and constructionist approaches and connecting these learning situations from the users' life worlds with more

formal learning environments through orchestrated collaboration. Assignments to construct multimodal representations in situated, real-life learning environments enhanced the students' "situated awareness": It made them observe, scan and reflect on their life worlds more consciously and deliberately (Uzunboylu et al., 2009, Seppälä and Alamäki, 2003) and connect their observations with concepts and knowledge from formal education. In this way, prior conceptions could be used as foundations upon which to "hang" relevant impressions. These filtered and substantiated 'lived' experiences are again connected with more formal educational spaces in the form of immediate or follow-up collaboration with peers and lecturers in virtual spaces (Seppälä and Alamäki, 2003, Hsu and Ching, 2012) and/or in the classroom (Ros i Solé et al., 2010, Lan et al., 2012). In these integrated settings, the affordances offered by mobile technologies are evident and can hardly be operationalised through other digital or non-digital formats: for example, portability and increasing ownership allow activities to be embedded in learners' daily practices. Multimedia capacities enable the digitisation and multimodal *re-presentation* of learning experiences, and connectivity is a pre-requisite for instant and sharing and collaboration.

Studies that involve hybridisation by connecting situated, constructionist and collaborative learning provide convincing arguments for what is viewed as the core of mobile learning: the facilitation of learning across multiple contexts, as defined by Sharples et al. (2007) or Pachler et al. (2010). Context crossing also incorporates the integration of formal and informal learning environments. This aspect is frequently stressed in mobile learning literature (Cook et al., 2008b) and also in other related domains, such as personal learning environments (Dabbagh and Kitsantas, 2012). Although authors acknowledge that this process extends formal classroom-bound and teacher-guided education with learning practice driven by the interests of the students (Wong and Looi, 2011), it is rarely explained how pedagogical benefits play out through the integration of these two worlds. As shown, studies with hybrid designs provide further insights into this process: They associate this integration with enhanced "situated awareness" outside the classroom, i.e. rendering unconscious learning and meaning-making more deliberate and tying it to prior conceptions. In turn, through the multimodal substantiation of 'informal' learning episodes and their acknowledgement and discussion back in more formal settings, the reconciliation of formal curricular knowledge and the learners' live-world learning experience is facilitated. Notions of formal and informal learning are, however, very vague and need to be clarified in this context: Regarding hybridization, the notion of 'informal' does not mean unplanned or voluntary. Instead, in all the studies, learning goals and the nature of the tasks were clearly pre-structured by the educators. Only the initiation (time) and the specific geographical and cultural environment of the "outside" learning episodes were not pre-determined. As indicated, also the re-integration of the life-world experiences was not left to chance but formed an integrated part of the didactic design, closely guided and supported by educators. Instead of speaking of "informal learning, it is thus more appropriate to conceptualise hybrid designs by enhanced levels of personalisation, because it allows learners to connect prior knowledge with their own private life worlds and bring these substantiated experience back into the virtual or 'real' classroom.

Regardless of the use of technology, the consideration and integration of multi-faceted educational practice outside the classroom only minimally represents the reality of today's higher education, which is characterised by environments in which lecturing - i.e., classroom-based and one-directional communication - are the main route of education (Deroey and Taverniers, 2011, Apel, 1999, Gehlen-Baum and Weinberger, 2014). Such conditions certainly do not facilitate the integration of situated, collaborative and constructionist learning, as described in the studies. Mobile learning can help to expand narrow and restricted educational curricula and connect learning within and outside higher education environments. The key to achieving these goals is, however, not the implementation of technology, but educators who create new and extended learning designs that link the different pedagogical strategies highlighted in this review. What can be learned from the past, and, what has also been confirmed in this review, is that the simple availability of creative and apparently empowering media does not per se lead to changed and enriched learning and teaching practices in higher education. In contrast to the expectations of a "revolutionary" change in higher education through mobile

technology, past and recent studies, in line with previous mobile learning reviews (Arrigo et al., 2013, Frohberg et al., 2009), do not seem to make an exception here. Most of the projects included in this study followed classic instructionist and behaviourist paradigms, and the richest and most creative pedagogical category, the hybrid design, had only a limited number of studies. The finding that technology is used (at least initially) to support pre-established teaching practices and that there is no comprehensive use made of its creative potential is not new and has been revealed also in other fields. For example, a review on the educational adoption of the social network site Facebook in education comes to the conclusion that, irrespective of the platform's connectivist features, it is rather used as "fenced space" that harbours traditional forms of content delivery and instruction (Manca and Ranieri, 2013). The authors explain this with implicit institutional, teacher and student-related pedagogies and cultural issues. Also Cuban et al. (2001) link the reasons for a conservative approach to the adoption of educational technology to contextual factors. These include limited time for the preparation of lectures, restricted opportunities for a cross-departmental exchange which, in turn, inhibits the cross-fertilization of new ideas. Another constraint is that, instead of systematically leveraging the qualities of ubiquitous technology to extend narrow designs, today's public discussion is focused on whether to ban mobile devices in the classroom or not (Barkham and Moss, 2012, Gao et al., 2014).

Limitations and directions for future research

This review represents only a snapshot of the current situation: most of the included studies are based on the evaluation of smaller portable devices, such as smartphones or PDAs. The findings are likely to change with ongoing technological development. For example, tablet PCs, which are increasingly used in higher education (Nguyen et al., 2014), or wearable technologies (McCann and Bryson, 2009) may offer qualities that differ from the ones observed here. Another limitation is that this review was systematic but not exhaustive. While the included papers met the defined quality criteria, the authors make no claim that these publications represent a comprehensive selection. In this sense, the focus on peer-refereed publications excluded other potentially high-quality contributions and grey literature, such as project reports, from the analysis. Another limitation is that the review explicitly searched for studies of mobile and ubiquitous learning. While this approach allowed for interesting insights into conceptualisations and understandings of this emerging and increasingly relevant field, it potentially excluded studies that incorporated elements of mobile learning without explicitly labelling them as such. However, the systematic search led to a considerable volume of high-quality contributions that offered relevant insights and formed a suitable basis for a thematic analysis (Bearman and Dawson, 2013).

To more comprehensively understand the meaning and role of mobile and ubiquitous learning in higher education settings, future research requires both qualitative and quantitative methods. This phenomenon constitutes learning across contexts, and the interaction of learners with and within these contexts needs to be explored by generating thick descriptions through qualitative, ethnographic techniques that can be linked to existing theories or can form the basis for developing new theoretical concepts. In this respect, many of the current qualitative investigations remain rather superficial and focus on reproducing learners' positive and negative experiences. One rare example was illustrated by Ros i Solé et al. (2010), who conceptualised rich insights into the learners' context-crossing that were interconnected with changes in self-concept following a socio-cultural understanding of learning. More generally, many of the qualitative or mixed-method designs should have been specified more in detail. That is, analytical techniques, e.g., how concepts emerged from the data, were only vaguely described, lacked details about the steps of the analyses. In addition, qualitative studies rarely reported validation mechanisms such as triangulation, intercoder agreement and respondent validation (Mays and Pope, 2000).

The analysis also showed that more elaborated quantitative approaches that measure changes from cognitive perspectives are required. Instead of testing knowledge recall (e.g., of vocabularies), as the majority of the instructionist studies did, future research is encouraged to evaluate "meaningful learning" (Mayer, 2002). This can be achieved using the following measures, which were applied in some of the studies considered for this

review: (1) quantitatively and qualitatively evaluating the students' interaction patterns (Lan et al., 2012) following an understanding of learning as interactional achievement (Koschmann et al., 2005); (2) measuring the learners' understanding of complex subject matters by coding and quantifying their responses to open questions (Zahn et al., 2013); (3) assessing their conceptual understanding by requiring learners to construct a concept map (Sung et al., 2010); or (4) evaluating the extent to which learners can apply their knowledge in practice situations via observation (Davis et al., 2013) or in new situations. The evaluation of learners' re-application of knowledge in new situations (as applied, for example in the mobile learning study by Pimmer et al. (2013) was not used in any of the identified studies. While these research approaches are certainly more time consuming, they represent the essence of what can be characterised as deep and meaningful learning in higher education. Notably, these approaches are not limited to researching instructionist learning; as the examples illustrate, they can and should be used to test situated, collaborative or constructionist designs.

Despite the range of higher education subjects, the dominant categories examined in the included studies were language learning, health and computer science studies. Thus, there is also a clear need to more extensively demonstrate the affordances and constraints of mobile and ubiquitous learning in other subject areas. It is also noteworthy that in most of the studies, a rather limited time span of a few months to a semester was examined. Thus, it is unclear to what extent the observed outcomes have to be ascribed to the novelty effects of using modern technology (Hew and Cheung, 2013). More mid- and long-term studies would be helpful to gain an understanding of how students' learning and conceptions are changing over time. These changes were impressively demonstrated by Tossell et al. (2014), who showed how dramatically students' perceptions of mobile learning experiences changed over the course of one year. For some of the identified learning formats, conflicting results were reported. This relates to the use of a dynamic scaffolding design in ill-structured situated learning environments where, for example, only half of the students found the mobile tool helpful for structuring the learning experience (Reynolds et al., 2010). Thus, more research is required to better understand the conditions and attendant designs of mobile learning that facilitate effective scaffolding in situated learning environments.

Conclusion

Instructionist qualities of mobile learning applications in higher education that are based on the presentational and testing capabilities of mobile devices can facilitate distributed and more frequent practice and can activate learners in and across classrooms. Beyond instructionism, the hybridisation of situated, collaborative and constructionist approaches via the use of mobile devices can also create new and unprecedented educational opportunities. This integration can result in situated awareness that connects knowledge from formal learning settings more directly with informal learning practices and, in turn, makes these educational experiences more readily available for later reflection and discussion in the classroom. Confirming previous reviews, the broad majority of mobile and ubiquitous learning studies showed positive effects. However, empirical evidence that would favour a broad application of mobile and ubiquitous learning in higher education settings is still limited. In addition, the expectation that mobile learning could transform higher education cannot be confirmed because the majority of the reviewed studies followed instructionist paradigms.

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