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ORIGINAL RESEARCH

Unpacking the Inherent Design Principles of Mobile Microlearning

Isa Jahnke[1] · Yen-Mei Lee[1] · Minh Pham[1] · Hao He[1] · Linda Austin[2]

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Abstract

Mobile microlearning targets a new audience of learners: employees and workers outside of offices, using smartphones for flexible, anywhere, anytime training. The term 'mobile' emphasizes that the content is made for small screens of smartphones. According to literature and industry reports, micro-lessons are generally between 30 s and 5 min. While research shows that mobile microlearning is a promising approach, it remains unclear how the current systems have been 'built': What are the underlying principles of such platforms? The goal of this study was to explore mobile-microlearning platforms and to unpack their inherent design principles. We applied different methods: First, we reviewed literature in both academic publications and industry reports in two iterative rounds. Second, we conducted interviews with industry professionals, e.g., directors and entrepreneurs of mobile- and micro-learning systems. Results show a set of 15 principles regarding technical issues, pedagogical usability of micro-content interaction and sequenced instructional flow. They can be used to detect issues and challenges in existing mobile platforms and may inform meaningful design principles for future development. The results expose that a more critical eye on the learning design implied in the small-screen platforms is needed e.g., future systems may include learning designs for higher order thinking skills.

Keywords Microlearning · Mobile-microlearning systems · Learning outdoors · Workplace learning · Smartphones · Mobile devices · Design principles

✉ Isa Jahnke
jahnkei@missouri.edu

Yen-Mei Lee
yl8qf@mail.missouri.edu

Minh Pham
minhpham@mail.missouri.edu

Hao He
hhv5b@mail.missouri.edu

Linda Austin
laustin.newstrain@gmail.com

[1] School of Information Science and Learning Technologies, University of Missouri, 303 Townsend Hall, Columbia, MO 65211, USA

[2] Donald W. Reynolds Journalism Institute, University of Missouri, 401 S 9th St, Columbia, MO 65201, USA

1 Introduction

Microlearning (micro-learning, micro learning) can be described as very short and bite-sized lessons, "what one has learned, in small, focused steps, (…) self-contained, with its own learning objective (…) as short as possible but as extensive as necessary" (Khurgin 2015, para. 1). Micro-lessons usually have a length of not more than 5 min. As our interviews with industry leaders show (read Results section later), they even argue for shorter lessons of 30–90 s. The term *microlearning* was used for the first time in 2003–2005 (Glahn 2017; Hug et al. 2005), however the '*mobile'* part is rather new. *Mobile microlearning,* first mentioned in 2012, is evolving as an emergent practice of corporate training and workplace learning: work-and-learn (Clark et al. 2018; Goggins et al. 2013). The term 'mobile' emphasizes that the learning content is created for the small screens of smartphones. The concept of *mobile* microlearning is especially interesting for learners outside traditional office environments who often use smartphones. One example would be journalists working outside in the field to cover the news; another would be employees at work who need quick solutions to problems. Whether outside or in their offices, they have specific learning needs, for instance, how to document information, edit a cell-phone video, or how to effectively present news, e.g., 'The 5 C's (Clear, Concise, Correct, Credible, Complete) of Writing News for Mobile Audiences.'

In the past years, there has been an acceleration of new mobile-microlearning platforms. Recent platforms include, for example, *Academy of Mine, Codecademy, CourseGuru, Coursmos, Edcast.com, EdX, FutureLearn, Grovo, Intellezy, Kajabi, Khan Academy, Lynda.com, Plurasight LLC, Ruzuku, Simplilearn, Skillshare, StoryMaker2, Summit Evergreen, TalentLMS, Teachable, Treehouse, Udacity, Udemy, Unleesh, and WiziIQ*.

Literature shows that mobile-microlearning approaches have increased over the past few years (Emerson and Berge 2018; Nikou and Economides 2018a, b). However, while industry has pushed toward such new learning platforms for different reasons (Cairnes 2017), the underlying design principles that guide the development of mobile-microlearning platforms are not sufficiently investigated.

2 State of the Art: What We Know About Mobile Microlearning

In recent years, mobile microlearning, or microlearning with mobile devices, has drawn attention for workplace training and learning (Glahn 2017; Callisen 2016). Studies of mobile microlearning show employees' engagement to learn has been increased through interactive micro-lessons that go beyond watching short videos (Göschlberger and Bruck 2017).

Several studies indicate that mobile microlearning is a promising teaching and learning approach for specific learner needs with new teaching styles (e.g., Aitchanov et al. 2018; Dai et al. 2018). Studies of microlearning show improved student efficiency and new teaching approaches across disciplines, e.g., nursing education (Hui 2014), medical training and health professions (Simons et al. 2015), language training (Fang 2018), engineering topics (Zheng et al. 2019), and programming skills (Skalka and Drlík 2019). Studies have demonstrated that microlearning improves learners' motivations, engagement, and performance (Mohammed et al. 2018; Zheng 2015; Liao 2015; Kovacs 2015; Jing-Wen 2016; Dinger et al. 2017). The study by Nikou and Economides (2018a, b) compared paper-based

assignments with mobile microlearning and revealed that microlearning enhanced students' exam performance. Other research has emphasized that because of time limitations at the workplace, mobile microlearning may have the advantage of flexibly conveying factual knowledge into skills needed for the job (Decker et al. 2017).

However, literature also argues that more research is needed to identify a significant advantage for microlearning (Decker et al. 2017)—especially, there is a lack of awareness with false expectations about what microlearning can and cannot do (Clark et al. 2018; Baek and Touati 2017). Using smartphones can distract learners from their learning, e.g., they write text messages instead of learning (Andoniou 2017). Another set of research points to issues of accessibility, bias and cost (Kabir and Kadage 2017; Vrana et al. 2017). Studies reveal that not all learners have access, and limitations for people with disabilities exist. Also, relatively high costs can occur, making it not affordable for users, e.g., when streaming videos. Gender or race bias affect the design of microlearning negatively. Another set of studies points to the design problem of having too much information that cannot fit on small screens (Carter 2017; Kabir and Kadage 2017). Other issues include compatibility, slow transmission speed, limited computational power, lack of technical support, and shortage of contact opportunities (Vrana et al. 2017; Lau et al. 2017). To summarize the design challenges so far, they are.

- Too much information on small screens.
- No clear contact information (e.g., instructor).
- Use of smartphones may distract the learner.
- Accessibility, technical (e.g., Internet access) and affordability issues.

One of the major elements of microlearning that researchers have studied in the past years is gamification or gamified activities (Ahmad 2018) and its connection to microassessment (Nikou and Economides 2018a, b). Several studies point to the following design principles of microlearning (e.g., Park and Kim 2018; Yang et al. 2018; Cates et al. 2017; Sun et al. 2015, 2017; Nickerson et al. 2017):

- content (re-)design (gamified)
- instructional design: instructional flow
- the user's content-interaction, practical and gamified activities
- adjusted to learner needs

Overall, literature sketches a positive picture with advantages for learners. At the same time, the number of mobile-microlearning platforms is increasing. These developments made us want to look deeper into the pedagogical approaches inherent in these platforms. It has been insufficiently studied as to how the existing platforms have been *designed* in terms of the underlying principles that guide teaching and learning (Reinhardt and Elwood 2019). In this study, the goal was to unpack inherent design principles and decode characteristics of mobile-microlearning platforms targeted for outside learners and those in traditional offices.

2.1 Unpack the System: Reveal its Design Principles

Technologies or systems are designed by somebody. This person or team applied ideas and guiding principles—either they are aware of the principles, they have a certain consciousness about the design principles, or they 'just' design and develop without having any specific framework in mind. The kind of learning approach that is inherent in the materiality of the technology will also affect different kinds of learning and performance.

An example of design principles is Gagne's (1987) instruction model. He defined nine steps of instructions based on a behavioristic approach. His model gaining student attention, informing about objectives, presenting content, eliciting performance, giving feedback, and assessing performance. These nine steps can be 'translated' into technology that supports learning. There are many other frameworks that provide ideas of how to design for learning with technologies (Jonassen 1996), for example, cognitive approaches such as cognitive load (Sweller 2008) or active and meaningful learning (Howland et al. 2012), as well as problem-based learning approaches (Jin and Bridges 2014).

Depending on the design principles, that someone chooses—an instructional designer, a teacher, a software developer and so forth—a different kind of system will be created. It is therefore extremely relevant to unpack the system and to reveal the guiding principles; without them, the technology goals remain unclear, making it difficult to evaluate learning and improve it properly (Cerratto-Pargman and Jahnke 2019). Also, the learners may find the system not usable and not satisfying.

We did not pre-define a specific set of design principles for mobile-microlearning platforms; we rather wanted to unpack the design principles that exist in literature and in the industry; principles that professionals apply consciously or not. What are *their* guiding principles for mobile-microlearning systems? The central research question is: What are the underlying design principles of academic literature and industry professionals that are inherent in existing mobile-microlearning systems? The results of our study may support students, teachers, instructional designers, learning engineers, and system developers interested in creating effective and meaningful learning experiences with mobile microlearning.

3 Methods

The study was conducted in 2017 and 2018 in two phases. In Phase 1, the team explored existing microlearning approaches, especially platforms for smartphones. We conducted an academic literature review (Webster and Watson 2002) in two iterative rounds as well as a popular trade/press/industry review. Inclusion criteria in round one were (a) years from 2013 to 2017, (b) keywords that included: Mobile Microlearning, Micro-learning, Microlearning, smartphone learning, mobile app learning, mobile app microlearning and mobile learning. We used Google Scholar and the EBSCO Discovery Service database hosted on the Ellis Library platform. We did not include a search based on specific journals, but we applied an open search. The initial search revealed 64 academic articles. A cross-check was conducted to narrow the scope of the readings. We scanned abstracts of all publications and selected the most relevant ones. Finally, 39 articles were selected for detailed analysis. The selected articles cover 32 journals and 4 conference proceedings. The journal-impact factors (IF) range from 0.13 (Journal of Science and Technology) to 5.60 (Computers & Education). While nine are from high-impact factors (above IF = 2), nine others have an

IF = 1–2, and 21 have an IF < 1 or do not report any metrics because of being published in open-access journals or conferences.

In a second round, 1 year later, we scanned potential new articles published in the year of 2018 and newer. We searched Google Scholar with the key words of "mobile micro learning," "mobile microlearning," and "mobile micro-learning." We removed all items that focused on the technical infrastructure of the applications, such as new cloud services or sensors, and were not useful for our purposes. A total of 11 new articles were selected.

For the industry review in 2017, databases of Frost and Sullivan, Factiva, and Business Source Premier were used; 30 articles were selected for detailed review. The main keywords for the industry reports were: microlearning, micro-learning, mobile learning, microlearning features benefits, mobile microlearning application, microlearning success. In addition, the search included broader terms that have been used in combination with the microlearning term: market size, solution, applications, user type, analysis, forecasts, corporate training, Udemy, Online learning, effective learning, personalization, Global corporate, e-learning market, growth, Americas, key elements, Trends, growth of micro learning, corporate education, design tips, microlearning features and benefits, ROI (return of investment), Coursera, Udemy and success, Coursera, and success, Udacity/advantages/support, Udacity/lessons.

In Phase 2, we conducted semi-standardized interviews in 2017 with industry professionals based on purposeful sampling (Palinkas et al. 2015). The sample was selected based on (a) the professional's experience level and (b) people that are highly regarded industry leaders familiar with mobile microlearning. This included industry leaders with more than 15 years of experience such as directors and founders of microlearning systems, start-ups, and innovators of microlearning companies. We identified 12 potential candidates who could offer information-rich expertise regarding mobile microlearning. Five industry leaders accepted the interview.

We applied semi-standardized interviews with an interview protocol (Jacob and Furgerson 2012). The protocol was divided into six sections including 22 questions in total. Twelve of the 22 questions where red color-coded as the most important questions; the other questions were asked if time permitted. The six sections addressed the following: (a) Information about the interviewee and his/her experience with microlearning platforms, (b) Whether or not the interviewee used an evaluation tool to measure the success of the platforms utilized, (c) Types of skills best taught in mobile microlearning, (d) Course structure and presentation of the micro-lessons, (e) Successful experiences using microlearning platforms, (f) Aspects of problematic issues.

The interviews were conducted in Fall 2017 online using the Zoom meeting tool. The interviews lasted from 59 min to 1 h and 34 min; the average interview was 66 min. The sessions were recorded. The interviews focused on understanding successes and failures in microlearning from an industry viewpoint.

Data from literature review, industry reports and interviews were analyzed to discuss the inherent design principles of mobile microlearning and further used to develop a set of heuristics to evaluate existing mobile-microlearning platforms. For the data analysis, we applied the thematic analysis method (Ely 1991) and the constant comparative method with the goal to form categories of design items. We compared one segment of data, e.g., one article or on interview, with another segment of the same article or interview to detect similarities and differences. Data are grouped together on a similar dimension. The dimension was tentatively given a name; it then became a category or cluster (Merriam and Tisdell 2015). Open coding and axial coding used across data have been applied together.

In detail, there were two steps:

- Step (1): For the analysis, we coded the design items, design challenges and design principles in each article and listed the items for each article separately, and then, we clustered the items into broader themes until the clustering or grouping process was saturated. This process was guided by two principles (a) putting similar design items into the same category, (b) but not losing the details of the items. We applied this procedure separately for the academic articles, industry reports and the interview data. In short, the emerging bottom-up semantic codes became the label of the 'design principle cluster' in each of the *three data sets*: (a) academic literature (A), (b) industry reports (IR) and (c) interviewed persons (IP). The results of each data set are presented in the Sects. 4.1, 4.2 and 4.3.
- Step (2): Then we triangulated the data: based on the design items, challenges or principles that we identified in each data set, we combined the results of the three clusters and analyzed similarities or differences of the design items and clustered them again. The results are reported in Sect. 4.4.

The entire data analysis was iterative and recursive and was guided by the constitutive elements of user-experience studies. Three researchers worked first individually to analyze the data. Each started with open coding, being open to anything possible (Merriam and Tisdell 2015) for each document or transcribed interview we had. Then we sorted comments and notes obtained from open coding to categories via the use of axial coding. Then each moved to the next document and started the process of open coding and axial coding again. We used the constant comparative method to compare the results we obtained.

To ensure the credibility of our study, emerging findings from individual analysis were discussed and compared by peer triangulation. We checked data by peer agreements, where at least three and up to five researchers checked the analysis of the data with a communicative validation using intersubjective methods to prove the quality of the research outcomes (Creswell 2009).

4 Results

We present the results in three sections: academic literature, industry reports, and interview results. (Read Sect. 3 how the categories were formed.)

4.1 Academic Literature

We reviewed 39 academic articles (read Sect. 3 for how we selected them). Nine articles focused on microlearning as an innovative trend for workplace learning; read Table 1:

13 articles emphasized the relevance of creating a microlearning approach for a "mobile" device such as smartphones or tablets; read Table 2:

17 articles highlighted the *mobile learning* approach in microlearning, e.g., mobile assessment; read Table 3:

One year later, after the first analysis, we conducted the same analysis for 2018–2019 articles. Eleven new articles were identified; they are listed in Table 4:

Table 1 Academic articles that relate to microlearning trend for workplace learning

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
1	Butgereit	(2016)	Gamifying mobile micro-learning for continuing education in a corporate IT environment	This paper uses mobile microlearning for continuing education and training of IT workers during their employment with the goal to stay abreast of new trends, techniques, tools, and utilities. *Design items*: gamified activities with QR and treasure-hunt methods
2	Callisen	(2016)	Why micro learning is the future of Training in the workplace	The article justifies microlearning at the workplace. *Design principles*: limitation of human attention span, flexibility of learning anytime anywhere, mobile friendly content. *Design items*: access to a library of modules for new and ongoing training. Small bits of information, and interactions
3	Gassler et al.	(2004)	Integrated micro learning: an outline of the basic method and first results	The article emphasizes repetitive learning and integrating learning into daily routine. *Design items*: time for each micro-task should not be too long, and learning process should be interactive
4	Giurgiu	(2017)	Microlearning an evolving e-learning trend	This article describes microlearning with the following *design principles*: Learners can learn snippets of information within a few seconds up to 15 min. Only one topic or idea. Information is retrievable. Learning cycle has dynamic and flexible structures, designed for learners to solve practical problems. Learners can build the learning structures at their disposal through exploration and social interaction (flexible learning pathways)
5	Kamilali and Sofianopoulou	(2015)	Microlearning as innovative pedagogy for mobile learning in MOOCs	The article emphasizes microlearning as an innovative pedagogy with the following *design principles*: short learning activities and lessons, compatible with a variety of devices, and enabling anytime-anywhere learning
6	Paul	(2016)	Microlearning 101	The article describes the benefits of microlearning, how to maximize it, when to use it, and how to assess it. *Design principles*: break lessons up into core information units, build an "aha" moment, create or base on practical problems for learners to solve, make problems relevant to learners, and respect learners' autonomy and achievement

Table 1 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
7	Rajala	(2016)	Making training mobile	This article presents a technology platform with retrievable video content. Searchable video content is suggested to make mobile training more efficient. *Design principles*: employ QR codes; focus on one topic or idea; video content is interactive
8	Rao	(2014)	Microlearning from the KM perspective	This article presents the main takeaways from the Microlearning Conference. *Design principles:* promotes learners at the workplace; micro-activities should help learners construct knowledge by themselves rather than merely consume knowledge; self-directed learning environments; recognition of learners' achievements; shared learnings; applicability of acquired skills to the workplace
9	Tipton	(2017)	Maximizing microlearning	The article demonstrates the problems of current training situations and how microlearning helps to solve the issues. *Design factors*: short efforts; one idea or concept at a time; "just-in-time" learning; content accessibility across devices; content in a variety of formats

Table 2 Academic articles that relate to microlearning for mobile phones or mobile devices

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
1	AlTameemy	(2017)	Mobile Phones for teaching and learning: Implementation and students' and teachers' attitudes	The study investigates the use of mobile phones. Students show more positive attitudes. *Design principles:* Learners need to understand the importance and efficiency of developing skills by mobile microlearning; learners need to have a sense of prior concepts that professional skills can be brought about by mobile phones; microlearning entails needed skills that are required for the lesson
2	Anshari et al.	(2017)	Smartphones usage in the classrooms: Learning aid or interference?	The study investigates smartphones as part of classrooms to enhance learning. *Design problems*: Smartphones have the potential to become more of a distraction than a tool to support learning; students easily get addicted to using smartphones
3	Bursztyn et al.	(2017)	Increasing undergraduate interest to learn geoscience with GPS-based Augmented Reality field trips on student's own smartphones	The study examines the impact of augmented reality (AR) field-trip exercises. Exposure to and completion of three mobile AR field trips had a significant impact on student interest to learn the geosciences. *Design challenges*: Gender or race bias in the design may fail the mobile learning. *Design principles:* Setup tasks for practical situations and with relevant photos, images, and pictures; support student interests and motivations; be flexible enough; be accessible and use inexpensive sources; consider the age range of target audiences
4	Carter	(2017)	Expanding access to learning with mobile digital devices	This paper studies how the use of mobile technology expands learning opportunities. *Design challenges*: involve meaningful interactivity or involve students in the opportunity to use technology to create their own content; technical issues such as less access to broadband internet and less access to one-to-one computing opportunities; offering feedback for the learner on areas where further practice may be necessary; rather than just being the recipient of content designed by others, learners become more motivated and develop stronger skills; provide opportunity for adults with learning disabilities

Table 2 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
5	Cruz et al.	(2017)	A game for learning history on mobile devices	The paper studies whether a mobile game on history content can lead to learning. *Design items*: gamified activities, games on mobile devices can motivate students to search for more information. *Design principle*: repetition of tasks in games allow for the development of cognitive skills or motor dexterity
6	Kabir & Kadage	(2017)	ICTs and educational development: The utilization of mobile phones in distance education in Nigeria	The study identifies challenges that need to be addressed in order to sustain and succeed in the implementation of mobile learning in Nigeria. *Design challenges:* small-screen size, cost of connectivity and devices, constant need to keep a mobile device charged, increase in stress levels, or feelings of overload by both learners and facilitators
7	Kim et al.	(2017)	A smartphone application to educate undergraduate nursing students about providing care for infant airway obstruction	The study examines a smartphone-based application for nursing students that measures their knowledge and skills. *Design items*: video and audio instruction. *Design principle*: less text, more graphics-based materials, instructions and use of appropriate reading level for appropriate students
8	Lau et al.	(2017)	Educational usage of mobile devices: Differences between postgraduate and undergraduate students	The article presents the differences of the user needs between undergraduate and postgraduate. *Design challenges*: small-screen size, long loading time, customization of learning content (personalized learning)
9	Lee et al.	(2017)	A smartphone-based activity-aware system for music streaming recommendation	The study examines a smartphone-based mobile system for music recommendation based on human activity recognition and evaluates the performance of an activity-aware framework. *Design challenges*: human-activity recognition, collaborative filtering methods, various activities, content-based recommendations for learners
10	Mamba & Kohda	(2017)	Smartphone applications improve high school students' learning achievements	The study explores mobile phones and their newly emerging features to enhance learning in a high school. *Design challenges*: peer interaction; interaction with tutors or instructors

Table 2 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
11	Shooriabi & Gilavand	(2017)	Investigating the use of smartphones for learning purposes by Iranian dental student	The study investigates the use of smartphones for learning purposes by Iranian dental students. *Design challenges*: having student use smartphones more for learning purposes (not for entertainment only)
12	Twum	(2017)	Utilization of smartphones in science teaching and learning in selected universities in Ghana	The study examines the use of mobile phones and how it influences science students' learning. *Design challenges*: distraction to learning, easy access, and fast sharing. *Design principles:* various tasks are needed
13	Yamamoto & Uchida	(2017)	Improvement of the interface of smartphone for an active learning with high learning concentration	The study introduces an interactive learning process, an active learning cycle, and proposes an interface of an active-learning system on smartphones. *Design challenges:* to improve learners' motivation, offer a well-designed interface for the learning system; provide learner choices for the learning content: different content, speed and difficulty levels to elevate students' motivation level. An improved interface of a learning system may increase students' learning motivation

Table 3 Academic articles that relate to the design of 'mobile learning' or m-learning

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
1	Asiimwe et al.	(2017)	Practices and challenges in an emerging m-learning environment	This study reports about a case at Makerere University in Uganda. They report the following *design principles*: Content-development practices, educational-content development, and teacher-training programs are crucial success factors
2	Baek & Touati	(2017)	Exploring how individual traits influence enjoyment in a mobile learning game	The study explores game enjoyment. A link between intrinsic motivation and enjoyment was evident (the more intrinsic motivation, the more enjoyment). *Implication for design*: address learner needs (intrinsic motivation) to enhance microlearning enjoyment
3	Biloš et al.	(2017)	Mobile Learning usage and preferences of vocational secondary school students: The cases of Austria, the Czech Republic, and Germany	The study looks at mobile-learning usage and adoption in vocational education. *Design factors* for users to use mobile devices include: (a) Getting access to the "progress report (notifications)," (b) Easier access to content or coursework, (c) Increased knowledge, (d) Increased communication. Obstacles with mobile learning can be technical issues such as limited Internet access, preference for laptops not smartphones, and previous IT-assisted experience
4	Chee et al.	(2017)	Review of mobile learning trends 2010-2015: A meta-analysis.	The article shows that studies of m-learning until 2015 focused on higher education and schools, not so much on workplace learning. Implications for *design challenge*: Potential of mobile learning for workplace settings is under-researched
5	D'Errico	(2016)	Mobile learning: What's it good For? Absolutely everything (that needs to be done now)	The article demonstrates the current situations and practical strategies of microlearning. The study shows the efficiency of learning outcomes and skills for quickly closing knowledge gaps. *Design items*: snackable content, bite-sized training; short and easy-to-consume ideas; relative ease-of-use, engaging presentation of content
6	Griol et al.	(2017)	Incorporating Android conversational agents in m-learning apps	The article presents the feasibility of multimodal interfaces for m-learning apps. Result: Learners achieved the highest satisfaction when they were able to switch between modalities. Implication for *design principle*: have flexible learning pathways

Table 3 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
7	Kaliisa & Picard	(2017)	A systematic review on mobile learning in higher education: The African perspective	The article presents mobile-learning results published between 2010 and 2016. The findings indicate *design principles* of mobile learning: enhanced interaction and collaboration, increased student participation and engagement, increased authentic learning and reflective practice, and promotion of learning communities. *Design items*: technological infrastructure constraints, access to mobile devices, pedagogical skills among teachers, attitudes toward mobile learning, incompatibility of mobile devices with learning-management systems, no guide to how to implement mobile learning
8	Khaddage et al.	(2016)	Advancing mobile learning in formal and informal settings via mobile app technology: Where to from here, and how?	The article presents a framework of mobile-learning implementation challenges and possible solutions. Mobile learning occurs in formal and informal settings; this creates the challenge of finding appropriate and effective methods to blend both. The article points to four *design challenges*: Pedagogical, technological, policy, and development issues
9	Lin et al.	(2017)	The measurement and dimensionality of mobile learning systems success: Two-stage development and validation	The article presents an instrument to assess mobile-learning systems. Success factors/*Design items:* free choice over when, where, and how to learn; portability; instant connectivity to content; context sensitivity; timely feedback
10	Nikou and Economides	(2017)	Mobile-based assessment: Investigating the factors that influence behavioral intention to use	The article identifies factors that affect user acceptance of mobile-based assessment. The findings show that students' behavioral intention to adopt mobile-based assessment depends on a combination of *design items*: environment, educational factor, user profile, mobile device

Table 3 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
11	Nickerson et al.	(2017)	Mobile or not? Assessing the instructional value of mobile Learning	The article shows the influence of mobile learning on students: acquisition of conceptual knowledge and development of their communication skills. Main findings: Mobile learning leads to an improvement in student performance compared with a traditional learning approach, especially when students are asked to demonstrate that they can apply their relevant disciplinary content knowledge. *Design item*: a specific instructional flow of *interact, produce, reflect*
12	Oyelere et al.	(2017)	Design, development, and evaluation of a mobile learning application for computing education	The article presents results of the MobileEdu application: it has a potential to improve student learning achievements in computing skills. *Design principles*: topics or skills in computing, such as programming, algorithms, operating systems, and software engineering
13	Shen et al.	(2017)	Analysis of social media influencers and trends on online and mobile learning	A study of how social media (Twitter) influences online learning and mobile learning. Implication/*Design principles*: hashtags can be used in microlearning to connect learners
14	Tongdee et al.	(2017)	Leopold's maneuver mobile learning technology for facilitating knowledge application and self-reported confidence of preclinical medical students	This article evaluates mobile learning for medical students. Mobile learning increases the learner's knowledge and confidence in psychomotor skills. Implication/*Design principles*: microlearning can enhance knowledge acquisition of specific content
15	Vrana et al.	(2017)	Supporting mobile learning: usability of digital collections in Croatia for use on mobile devices	This paper presents user interfaces of digital collections in libraries. *Design principles*: content should support different screen sizes, be accessible on new and old mobile devices, and provide a variety of functionalities for users
16	Wang et al.	(2017)	Design of a new mobile-optimized remote laboratory application architecture for m-Learning.	The article shows a remote laboratory and how mobile devices can be used to connect to the lab to conduct remote engineering tasks by users. *Design principles*: content presentation, interaction with the remote lab, and the student receives the data of the engineering experiment for further analysis

Table 3 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
17	Wang	(2017)	Integrating self-paced mobile learning into language instruction: impact on reading comprehension and learner satisfaction	The study investigates a self-paced mobile learning in a language course in comparison to a traditional course. Mobile-learning learners scored higher test results. *Design principles*: student interact with the content, graphics, and multimedia

Table 4 Academic articles that relate to mobile microlearning published in 2018 or later

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
1	Dale et al.	(2018)	Smartphone app uses loyalty point incentives and push notifications to encourage influenza vaccine uptake	The article presents a study of the users' understanding of influenza and its vaccine through an educational quiz in a mobile app with the goal to determine if mobile "push" notifications and loyalty point incentives increased users' visits to pharmacies and their receiving of the vaccine. *Design principles*: Push notification will not change users' behaviors unless it has a sufficient number of prompts. The amount of incentives must be meaningful to users to influence their behaviors (e.g. keep engaging in the app). Learning content in a mobile platform needs to be adapted to make the learning more effective for mobile microlearning
2	Gao et al.	(2019)	A framework of learning activity design for flow experience in smart learning environment.	The article uses the flow experience theory (Goals, Feedback, Skills match challenges) to design learning activities. The design increases engagement and promotes learning performance. *Design items*: flow experience and learning engagement
3	Harris	(2018)	Gnowbe–the latest guest to the platform party is distinctly mobile.	The article describes the design of a mobile-learning application (Gnowbe). *Design items*: small cognitive load via segmenting learning into parts, e.g., mini scaffolds with five-minutes-a-day usage; learners are being able to share, read the opinions of other learners on a discrete piece of shared content and then share again on a platform. The immediate follow-up, multiple-choice questions are made for a "prepare-experience-reflect" journey
4	Javorcik and Polasek	(2018)	The Basis for choosing microlearning within the terms of e-learning in the context of student preferences	The article discusses the learner perceptions and preferences of current e-learning courses transformed into microlearning. *Design items* include the division of subject matter knowledge into small units/small batches of 5 min (granularity), a reinforcement question for the learner at the end of each unit, optional follow-up materials, the creation of a dictionary, (e.g. related terms), interactivity, e.g., quizzes, and feedback

Table 4 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
5	Jiang et al.	(2018)	The design of mobile learning resources based on WeChat	The article describes support for mobile learning on the WeChat platform and proposed design items for mobile-learning resources. *Design items* include: interactive navigation of resources, segmentation of knowledge, real situational tasks to stimulate and cultivate the learner's interest in learning
6	Nikou and Economides	(2018a, b)	Mobile-based micro-learning and assessment: Impact on learning performance and motivation of high school students	The article describes an experiment to study the impact of microlearning content and assessment on learning performance and motivation. *Design challenges* mentioned in the study: use of mobile microlearning to support learner autonomy, self-directed learning and sense of community. *Design items* include: microcontent units each focuses on a single important point; close-ended questions with immediate emotional and/or cognitive feedback; and a peer-learning online forum to seek help, share and post materials
7	Norsanto and Rosmansyah	(2018)	Gamified mobile micro-learning framework: A case study of civil service management learning	This article presents a gamification framework regarding the design of microlearning systems. The framework is based on the instructional-design framework (ADDIE) combining a gamification framework and microlearning-design principles. *Design principles* include: integrating relevant pedagogical strategies, situational-learning tasks, collaborative learning activities, microlearning materials, and promotion of community learning. *Design items*: identify gamification objectives, analyze needs of users, and establish a system design with feedback for learners' progress, including badges as rewards for completing sub-missions, leaderboards, and learner levels

Table 4 (continued)

#	Source (alphabetical order)	Year	Title	Major design challenges, principles or items addressed in the article
8	Schneegass et al.	(2018)	Informing the design of user-adaptive mobile language learning applications	The study goal is to understand how users use mobile language-learning apps in different contexts and provide design recommendations for these apps. The *design challenges* are: reducing users' tiredness; increasing users' attention levels; having the app adaptive to various use scenarios, and keeping users motivated (via intrinsic motivation)
9	Yun and Zhengqiu	(2018)	Characteristic personnel training and teaching reform via advanced centralized practice courses under the new format of Internet	This study introduces a curriculum-reform model to help workplace learners to get a learning/training experience and more practice by using mobile microlearning. It reports the effectiveness of the implementation of this model. The *design challenge* is: provide learners with more opportunities to practice on mobile apps. *Design items* include an app that allow learners to "micro-experience," "micro-practice" and "micro-combat" their knowledge and skills
10	Zhao et al.	(2018)	Stationary vs. non-stationary mobile learning in MOOCs	The study compares two scenarios for mobile learning: stationary scenario and moving scenario. The results indicate that moving scenario slightly affects learners' learning gains and learning consumption time. The *design challenge* is: allow learners to focus more when in a moving scenario. *Design items* include multiple task support in an app that helps users to focus when they are commuting or moving
11	Zhou	(2018)	The construction and application of micro learning environment under the background of new media	The article proposes a framework on how to design for micro-learning. *Design items* are: modularization of content, arbitrariness of learning time (learners can make use of scattered time without a fixed time or place for learning), diversity of learning media, individualization of learning (learners can selectively learn according to their interests and hobbies)

We clustered the content of the 39 articles (from 2017 and earlier) as described in the Sect. 3: first, we identified and listed the design challenges or items as mentioned in each article, and then, we clustered the items into broader themes. We did this in iterative steps until the clustering process was saturated. In a second step, we conducted the same analysis for 2018 or later articles.

Table 5 presents the four categories of mobile-microlearning design principles as analyzed from these aforementioned academic articles. Cluster 1 reveals principles connected to the redesign of content. This includes content-interaction, single topics, small learning nuggets and the short time (2–7 min) for lessons. Cluster 2 lists design items with regard to the instructional flow, e.g., flexible learning pathways with a flow experience for the user, gamified activities, practical exercises, instant feedback and interaction with peers (e.g., collaborative or community learning). Cluster 3 includes items related to the system design such as easy access to the platform via smartphones, a learning-progress reward system, and offline services. Cluster 4 lists items that include motivating the learner and addressing learner needs.

4.2 Reports from Industry

The 30 articles from industry that are listed in "Appendix" were reviewed (read Sect. 3 how we selected them); 14 articles were published in 2017, 8 articles in 2016, 6 articles in 2015, and 2 articles were published before 2014. While the data from the academic literature review could be clustered into four main areas, the data from the industry reports were more detailed, focused on concrete or practical issues, and revealed additional factors; read Table 6.

Cluster 1 focuses on the content redesign, and this includes design items such as short-time micro-nuggets, single topic and responsive design. Cluster 2 is titled instructional flow and includes items such as flexible learning pathways. In contrast to the academic literature, the Industry reports add new design items, e.g., less emphasis on lecturing and more on student-content interaction, supporting learner reflection and a newly arranged sequence of micro-content. Cluster 3 lists items regarding the system features, for example, accessibility design, tracking learner progress, and language support. Cluster 4 adds design items that focus on the learner needs. Clusters 5–7 are new items that were not mentioned in the academic literature. Cluster 5 obtains items for a supportive environment, e.g., helps learners when they get stuck. Cluster 6 includes design items related to cost and affordability. Cluster 7 shows design items such as including certificates, specializations or degrees.

4.3 Interview Results

The goal of the interviews was to challenge, confirm or identify further inherent design principles of mobile microlearning as presented in Sects. 4.1 and 4.2, Tables 5 and 6, A = Academia, IR = Industry Reports. The interviewees emphasized that a microlearning lesson should focus on a single learning objective, topic, concept or idea and help users do just one thing optimally; that is also mentioned in Cluster A1 and IR1: Micro-content, course length). This includes that learning content should be converted into *snackable*, bite-sized lessons. Industry Professional (IP) 1 provided the idea that giving *crammed* lessons does not help. Three interviewees said that a mobile-microlearning platform should have lessons with interactive elements so that learners can practice and/

Table 5 Unpacked design principles of mobile microlearning from academia (A)

Clusters (*A* academic literature review)	Articles
Cluster A1: Redesign content: micro-content, micro-activities	
A1.1 Supports interaction with content	27
A1.2 Offers small/single chunk and single topic, easy to understand	21
A1.3 Arranged in short-time spans (2–7 min., exact time not agreed)	17
Cluster A2: Instructional flow (new arrangement of pedagogies)	
A2.1 Supports multiple, flexible learning paths, flow experience	17
A2.2 Includes different media formats (graphics, videos, quizzes, etc.)	14
A2.3 Includes gamified activities	8
A2.4 Practical exercises and hands-on tasks	7
A2.5 Provides instant feedback after/during the session (assessment)	6
A2.6 Interaction with peers, collaborative/community learning	2
Cluster A3: System design	
A3.1 Supports easy access to the platform	15
A3.2 Allows learner to track her/his learning status (progress), badges or point system as rewards, leaderboard, learner level	7
A3.3 Allows offline-services, smartphone version	6
Cluster A4: Addresses needs of learners, motivates	
A4.1 Does support or encourage learners to 'discuss' their needs	11
A4.2 Does increase learner motivation	11
A4.3 Considers total age range of the target audiences	2

An article can be clustered more than once; content may fit different clusters

or apply what they have learned (Cluster A1 and IR1: Interactive micro-content). IP 4 concisely addressed this concept during the interview:

> Interactivity is important. People were not satisfied with their experience online because a lot of people were talking at them rather than having a way to try the way by themselves, which the latter is a really important part of learning.

The interviewees pointed to content that should be designed for learners to engage in problem-solving activities rather than purely listen to presentations. The industry leaders characterized the optimal mobile-microlearning platform as engaging, inclusive and self-paced. While the industry reports show the relevance of 'engaging the learner' as a design principle, the interviewees also emphasized the principle of 'self-paced' microlessons. Interviewees emphasized that lessons should guide learners in a flow, starting with aha-moments with examples and then shifting to how to transfer the knowledge. The successful design of microlearning, according to the interviewees, focuses on content that can be presented in diverse media formats and activities such as game-based learning, video, audio, quizzes, and so forth (read Cluster A2 and IR2: Instructional flow). As IP 1 said,

> … from just videos to a cart-based lesson platform. Every cart has different types of lesson formats like video carts, audio carts, quiz carts, and more. Learners can interact with carts and learn lessons that way.

Table 6 Unpacked design principles of mobile microlearning from *I*ndustry *R*eports (IR)

Clusters (*IR* industry reports)	Reports
Cluster IR1: Redesign Micro-Content	
IR1.1 Short-time, bite-sized micro-nuggets (not semester-long class)	4
IR1.2 Low complexity (single topic)	2
IR1.3 *Make it responsive, keep it concise	2
Cluster IR2: Instructional flow toward activity design	
IR2.1 Flexible learning paths; teachers don't over-plan learning by strict paths	6
IR2.2 Rewarding, engaging, motivating	6
IR2.3 Information packaged in rich media formats	2
IR2.4 *Provides clear instructional conditions (what to learn, who is learning)	2
IR2.5 *New, re-arranged, sequenced micro-content; range of activities	2
IR2.6 *Less emphasis on lecturing, more on student-content interactions	2
IR2.7 *Knows situational constraints (time, resources) of learners	2
IR2.8 *Supports learner reflection	1
Cluster IR3: System design	
IR3.1 Access when needed, to learn anywhere; downloadable, offline	6
IR3.2 System provides completion rate (e.g., tracking learner progress)	4
IR3.3 *Can be accessed on the device of learner's choice; multi-device delivery	5
IR3.4 *System saves activities and results; push notifications	2
IR3.5 *Provides language support	1
IR3.6 *For teachers: easy to update and reuse materials	3
Cluster IR4: Addresses learner needs	
IR4.1 Addresses learner's needs; aligned with needs	2
IR4.2 *Designed for the moment of need	4
IR4.3 Addresses attention-span problem of learners	1
**Cluster IR5: Supportive environment	
IR5.1 Smooth transition between personal environment & work environment	1
IR5.2 Microlearning as a space where learners feel connected to their peers	1
IR5.3 Connects learners and their cultural practices	1
IR5.4 Provides learners with a personalized learning experience	1
IR5.5 Supportive community; helps when learner gets stuck	1
IR5.6 Teachers are actively engaged and show their presence in the system	1
**Cluster IR6: Costs	
IR6.1 Should be affordable and efficient	6
IR6.2 Should be attractive such that users want to become members	1
IR6.3 Registered members enjoy certain privileges over non-registered	1
**Cluster IR7: Curriculum	
IR7.1 Offers specialization, certificates or degree	2

Items with ** highlight additional items not revealed in the academic literature as previously shown in Table 5. Items with * indicate partly new aspects of the same item as listed from the academic literature analysis in Table 5

According to the interviewees, good micro-lessons involve immediate feedback to enable users to correct performance on the spot. This relates to Cluster A2 and IR2: Instructional flow. IP 2 and IP 4 addressed this concept during the interview:

> Create personalized formative feedback based on quizzes' results. "Nudges to Mastery," quizzes inform gap areas, "nudge" the learner to practice said areas. (IP 2).

> If you want to get users, [have them] check out your new stuff by sending them the weekly digest, offer opportunities for learners to talk with experts (IP 4).

All interviewees mentioned the importance of focusing on topics that learners really need when they need it, and this relates to the Cluster A4 and IR4 of the literature review: Addresses learner needs. The interviewees argue that teachers should evaluate user needs before giving training and provide problem-solving training based on the context. All interviewees emphasized addressing individual learner needs and preferences and argued that short-term courses should be easily re-structurable. IP 1 emphasized:

> The moment of need to solve a problem immediately, the moment of motivation, and the moment when people are preparing for performance are the three best moments to give people learning experiences and resources.

Lastly, the interviewed industry leaders said that it would be good to have a dashboard in the system for tracking individual's learning status and creating short sessions. The platform would have a library or search function to browse content. This relates to Cluster A3 and IR3: System design. The interviewees proposed that the courses be designed across multiple technologies, so that learners can have more flexibility to learn on their own paths. As IP 2 pointed out during the interview:

> [The] same training/lessons (micro-learning) should be available across multiple devices (desktops, laptops, tablets, smartphones, etc.), enabling learners to learn on the device of their choice.

In summary, the interviewees put the emphasis on the following four clusters:

- Importance of micro-content: small nuggets (A1, IR1).
- Instructional flow: starting with aha-moments with examples and then shifting to how to transfer the knowledge, and learner interacts with content, receives feedback based on quizzes or other gamified activities (A2, IR2).
- Technical system requirements (tracking learner progress) (A3, IR3).
- Address learner needs in the moment of need (A4, IR4).

4.4 Inherent/Implied principles revealed—Results from data triangulation

In this section, we present the results of the data triangulation as we combined the results for the three data sets of academic literature, industry reports and interviews with industrial professionals. Results in Sects. 4.1–4.3 demonstrated several inherent design principles. When further analyzing the data across the three data sets by analyzing and grouping similarities and differences, and clustering the results further, the following major themes or meta clusters can be seen as presented in Fig. 1 and listed here:

1. Interactive micro-content.
2. Chunked courses.
3. Instructional flow of activity-based model of instruction.
4. System design for mobile apps.
5. Focus on learner needs.
6. Supportive social structures.
7. Costs and affordable subscription model.
8. Curriculum provides single lessons; may sum up into certificates or degrees.

For the eight condensed themes, the design principles can be described as follows (Fig. 1):

Interactive micro-content for closing practical skill gaps

1.1 Interactive content It engages users by requiring action using the content. A mobile-microlearning platform has lessons with interactive elements that learners can practice and/or apply what they have learned, e.g., simulations, drag-and-drop, quizzes.

1.2 Practical Problem-solving Content is designed for learners to be engaged in practical problem-solving activities rather than just listening to presentations or videos.

Chunked courses

2.1 Snackable, not crammed single topic The platform keeps the duration of lessons short. Ideally, the lessons are 30 s to not more than 90 s. Learning contents are converted into bite-sized lessons. Course segments are divided into small chunks. A micro-lesson is focused on a single learning objective/topic/concept/idea and helps users do just one thing optimally; it has low complexity.

Instructional flow of activity-based model of instruction

Activity based model of instruction assumes that the learner does not learn by the teacher's activity but through their own activities.

3.1 Instructional flow, sequenced, engaging Lessons are organized in a sequenced form provide learners with a clear sequence of activities: an aha-moment followed by the objective, examples and practice, concluding with a call for action and immediate feedback. They include how to do a concrete thing in an interactive, engaging way and give users real experiences but do not over-plan a strict learning path.

3.2 Rich of diversity of media formats. Content is presented in a diversity of formats and activities such as presentations, games, videos, audios, quizzes, and so forth.

3.3 Instant feedback Immediate feedback is available, enabling users to correct performance on the spot. It gives users feedback on what they need to work on and then subsequent lessons are tailored based on that feedback.

System design

4.1 App availability The platform supports mobile apps on different systems (iOS, Android, etc.), not only desktop versions. It is downloadable for offline use.

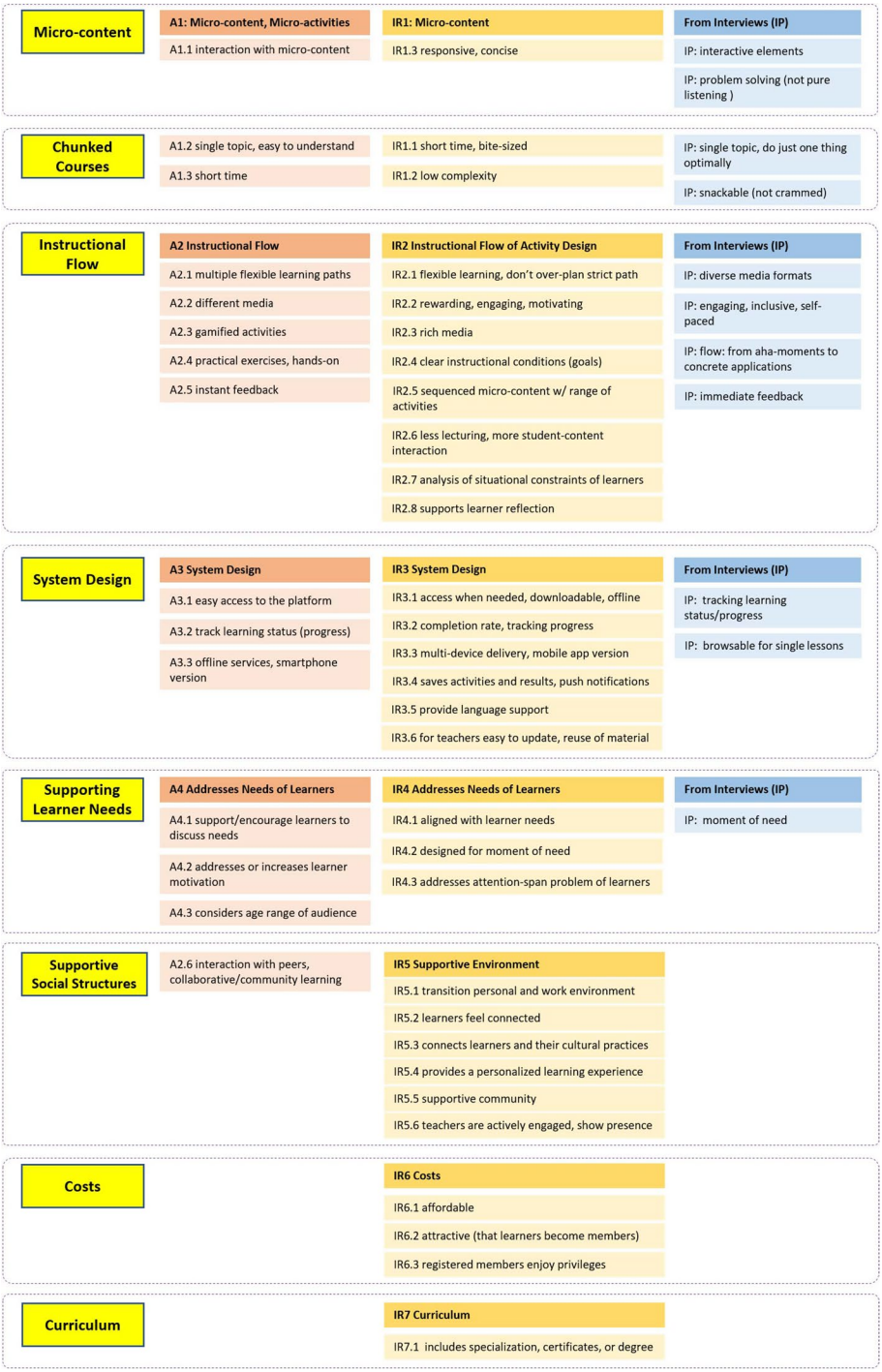

Fig. 1 Design principles inherent in mobile microlearning

4.2 Push notifications. It saves activities, sends notifications and has reminder features to support the daily habit of users; these can be optional if selected to be so by learners.
4.3 Track learning progress Lessons are integrated into a dashboard, which utilizes social features such as likes and views, contributions, curated content, etc. These components aid in the learners' awareness of their performance. The dashboard has links to resources, which help users to learn what is relevant to their performance. Performance support is provided with a dashboard that contains all things that learners need to do to boost their performance.
4.4 Browsable, independent, searchable micro-lessons A mobile-microlearning lesson can be part of a larger module or course and may include elements of courses, but at the same time, it is able to stand alone and be searchable at the moment of need.
4.5 Teachers can easily update the microlessons and reuse material.

Supporting learner needs

5.1 Moment of need It enables users to quickly gain knowledge at the moment of need; when a user has to 'solve' an issue immediately, s/he finds an existing lesson on the platform. The micro-lesson is aligned with learner needs.

Supportive social structures

6.1 Supports the connected learner in which learners get help or collaborate with peers or community, teachers are actively engaged and show their presence in the system.

Costs and affordable subscription model

7.1 Affordable Micro-lessons are not cost-intensive.

Curriculum provides single lessons; may sum up into certificates/degrees

8.1 Embedded into a broader curriculum Single lessons may sum up into a certificate or degree.

4.5 Pretesting the Set of Principles on Existing Platforms

To pretest the principles, whether they are distinctive and useful to become heuristics to evaluate platforms, the team applied them on seven mobile-microlearning systems. To select these seven out of 25 platforms (as listed in Sect. 2 previously), the team prescreened the platforms applying six questions:

- Mobile version: does the platform have a *mobile app* version?
- Course length: Short, not more than 5 min?
- Micro-content: does the platform have interactive elements?
- Instructional flow: does the platform support diverse media formats?
- Browsable: is there a library with on-demand content?
- Costs/subscription model: free or affordable for learners?

If the answers were 'yes' the system was selected for a detailed analysis. These were *EdX, Lynda.com, Skillshare, TalentLMS, Udemy, Unleesh, WiziIQ*. Three researchers applied the set of developed 15 mobile-microlearning heuristics (read section previously) to evaluate the platforms in detail. When applying these principles with a simple yes/no category, a ranking occurs in which the first one matches most of the principles:

1. EdX
2. TalentLMS
3. Skillshare
4. WizIQ
5. Unleesh
6. Udemy
7. Lynda.com

The courses built using these platforms vary greatly, and the features presented represent only the potential of each platform and not necessarily the way it actually is used. EdX matches all principles, and would therefore seem to be the most usable platform for mobile microlearning. TalentLMS, Skillshare and WizIQ match almost all of them and might still be usable for mobile microlearning. Three of them—Unleesh, Udemy and Lynda.com—match two-thirds of the heuristics. Courses in Unleesh, for example, can be found only by invitation. Udemy, for example, mainly offers videos/lectures as major learning activities. For journalists who want to learn IT skills used at their workplace, hands-on learning activities might be better. Lynda.com, for example, does not support the instructional flow from simple to complex. Our evaluation of the seven platforms identified some, but no major, problems of usability when applying this set of principles.

With this simple test, we wanted to make sure whether the principles are distinctive and meaningful to identify different qualities of platforms. Further research may provide more detailed categories beyond a yes/no category.

5 Discussion

Results show that the interviewed industry leaders believe that mobile-microlearning platforms have the potential to boost learning at the workplace in a new 'micro' way. However, when looking deeper into existing platforms and *design beliefs* of researchers and practitioners, it remains unclear how the platforms have been designed: What are their inherent theoretical foundations or design principles of mobile-microlearning platforms and what is the quality of learning?

We identified 8 major design principles that include a total of 15 sub-categories; read Sect. 4.4 for details.

The most interesting part is that the design of mobile-microlearning platforms is shifting from a pure video watching approach to a more activity-based model of instruction in which the learner reads or watches something but then s/he has to be active to apply the new knowledge. The question remains, what is the quality of learning?

5.1 Quality of the Inherent Design Principles: A Critical Eye is Needed

Mobile microlearning is particularly useful for workplace learning: it may help people to learn something small and quickly that is easy to learn. It may help people fit small units of learning into their hectic work (Shank 2018). In other words, microlearning cannot be used for all kinds of topics. We here discuss potential issues that the design principles revealed.

First, the unpacked 15 mobile-microlearning design principles show a similarity to Gagne's model of instruction (Gagne 1987). The inherent design principles of mobile microlearning focus on activities that can be summarized with four basic components—each micro-lesson, doable in about 8 min, follows this structure:

Information snippets:

1. Cues (a-ha moments) to showcase the relevance of the topic
2. Interactive content

Instructional snippets:

3. Short exercises in forms of quizzes or other gamified activities
4. Instant feedback (whether answers were correct or not)

This is aligned with Khan (2019), where *informational snippets* mean that the audience receives quick information and *instructional snippets* refer to the learning objects to learn something. The structure reveals that the element of reflection is missing. As Glahn proposes (2017), and so do other education researchers (Kolb 1994), learning does not take place without reflection. It is a future design and research challenge to rethink mobile microlearning toward reflective-learning approaches.

Second, mobile microlearning addresses a specific type of learning topics and outcomes, that are easy to learn, and that have a correct answer available. It includes the learning goals of 'understanding' but does not include higher-order thinking skills such as deep analysis of a certain topic (Bloom's taxonomy 1956).

Third, the design principles indicate that mobile microlearning is based on a rather behaviorist view. Its design is driven by the learner's *click-activities,* in which the learners learn by 'clicking' and not by creating artifacts or products (Cerratto-Pargman and Jahnke 2019). The learning design fosters learning *from* technologies and not *with* technologies (Jonassen 1996).

Altogether, the issues discussed here contribute to the broader discourse of *automating human activities* in the digital age, e.g., creating 'artifacts that think for humans' versus *enriching and empowering teachers and students with technologies*, e.g., creating 'artifacts to think with'. It seems that mobile microlearning tends to focus on the automation of learning and supports a learning approach 'where the answer is known' (Jahnke et al. 2017).

Despite these critics, mobile-microlearning approaches are not per se *un*-useful, however, it is crucial that this is not the only way of learning. We recommend design changes. Our world provides complex questions where the answer is not known yet (e.g., challenges of environmental issues)—and microlearning cannot help here, at least not how it is designed as of today. We therefore encourage mobile-microlearning designers and developers to offer different points of entry into learning: one can be the mobile-microlearning way

(e.g., to make people curious), and the other might be a deeper or meaningful approach—one can build on the other to encourage learners to go into the details. In addition, as shown by Major and Calandrino (2018), a revised mobile-microlearning design can go "beyond chunking"; they illustrate how microlearning can be used for deeper learning as students were encouraged to use mobile devices to connect the subject matter with their everyday lives as well as the world around them. The main idea is that learners upload photos or short videos of what they have applied or created, and coaches give feedback in a timely manner.

Further research is needed for a more detailed study on how to make use of deeper learning in mobile-microlearning that permeates research and development of these platforms and that may also include a more critical discussion in terms of consequences and usefulness for learners in different contexts. Furthermore, future research may investigate how the here reported mobile-microlearning design principles can be turned into 'heuristics' with the goal to detect technological (e.g., usability heuristics by Nielsen 1999), social and pedagogical usability issues (Moore et al. 2014) that may lay the foundation toward heuristics of *socio-technical-pedagogical integration design* of mobile microlearning.

5.2 Limitations

For the method of the academic literature review, the team used articles mainly between 2015 and 2018. We based our study on the situation of 2017–2018 to evaluate the most appropriate platforms at the time. We could not include all platforms; e.g., Ed App was not part of our original study. In Phase 2, five interviewees were recruited in the study. Although the number of five users is a sufficient number for revealing usability issues of easy and not-complex systems (Nielsen 2012), further research may include additional users (Sauro and Lewis 2012; Faulkner 2003). They may help to unpack technical and pedagogical usability issues of mobile-microlearning platforms and to refine these heuristics—especially with regard to deep or meaningful learning approaches, not relying on behavioristic approaches only.

6 Conclusion

The results indicate that researchers and industry professions *believe in* mobile microlearning; it provides new strategies for instructional flow and combines snackable lessons (30–90 s per session) with diverse media formats, interactive content, gamified activities and instant feedback. Mobile microlearning is relevant for learners outside the traditional workplace or office environment. We unpacked the inherent design principles and developed a set of 15 heuristics for mobile microlearning for further use to evaluate new and existing platforms. The results demonstrate a certain understanding of behavioristic level of learning of practicing, where one can learn how to edit a video or learn to write for mobile audiences, and does not involve higher-order thinking skills. The simple tasks embedded in mobile-microlearning systems target learners in a hectic workplace that need quick answers and solutions to continue with work. In such a way, mobile microlearning contributes to individual *training* at the workplace but not necessarily to creative, deep or meaningful learning.

Future research may study how the design of mobile microlearning can include an active deeper-learning approach targeting complex problems. We also suggest developing mobile micro-lessons for workplace learners in the field, e.g., journalists, to support their anytime-and-anywhere, work-and-learn environment, and studying the learner's experience (LX), efficacy and efficiency of those micro-lessons.

Appendix 1: Industry Reports (n = 30)

2017, Reap Big with Small—5 Ways Microlearning Gives Better ROI http://blog.commlabindia.com/elearning-development/micro-learning-roi.
2017, Mobile Learning: Form the Learner's Perspective http://www.elearninglearning.com/2017/micro-learning/mobile-learning/?open-article-id=6719096&article-title=mobile-learning—from-the-learner-s-perspective&blog-domain=learnnovators.com&blog-title=learnnovators.
2017, Microlearning gets you the skills https://www.businessmanagementdaily.com/49929/microlearning-gets-you-the-skills.
2017, Micro learning—the big wave of mobile education http://www.elearninglearning.com/2017/micro-learning/mobile-learning/?open-article-id=6379633&article-title=micro-learning—the-big-wave-of-mobile-education&blog-domain=matrixlms.com&blog-title=matrix.
2017, Maximizing microlearning https://swissvbs.com/resource/maximizing-microlearning-guide/.
2017, Learning with Mobile Technologies http://proxy.mul.missouri.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip,cookie,url,uid&db=buh&AN=121487776&site=ehost-live&scope=site.
2017, Increase in Digitization to Boost the Corporate E-learning Market | Technavio http://www.businesswire.com/news/home/20171017006271/en/.
2017, How To Use Microlearning To Make Your Corporate Training More Effective https://www.eidesign.net/use-microlearning-to-make-your-corporate-training-more-effective-10-ways/?utm_campaign=elearningindustry.com&utm_source=%2Fcan-use-mobile-learning-apps-microlearning-based-training&utm_medium=link.
2017, Effective learning can't be a one-size-fits-all approach https://www.hrzone.com/talent/development/effective-learning-cant-be-a-one-size-fits-all-approach.
2017, Coursera focuses on corporate training programmes for future growth http://www.livemint.com/Education/tSGQPwXcSn2eBhz6ZQFI2I/Coursera-focuses-on-corporate-training-programmes-for-future.html.
2017, 5 Rules for Successful Microlearning https://www.td.org/Publications/Blogs/Learning-Technologies-Blog/2017/09/5-Rules-for-Successful-Microlearning.
2017, 12 Microlearning apps that are the perfect fit for your classroom https://www.bookwidgets.com/blog/2017/02/12-microlearning-apps-that-are-the-perfect-fit-for-your-classroom.
2017 eLearning Trends: Micro Learning https://www.eleapsoftware.com/2017-elearning-trends-micro-learning/.
2016, Udemy Thinks It's Cracked the Future of Online Education http://time.com/4215787/udemy-dennis-yang/.

2016, Udacity Graduate Kushal Sharma: Finding Success and a Job My Own Way, https://blog.udacity.com/2016/01/udacity-graduate-kushal-sharma-finding-success-job-my-own-way.html.
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