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Investigating the use of innovative mobile pedagogies for school-aged students: A systematic literature review

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ABSTRACT

The empirical evidence surrounding innovative technology-enhanced-learning practices in K-12 education is at best patchy. This study seeks to address this problem by investigating innovative mobile learning pedagogies for school-aged learners, including the extent to which these approaches may be disruptive to traditional school structures and practices. It adopts a rigorous Systematic Literature Review (SLR) methodology to interrogate this phenomenon, with fifty-seven high quality articles published between 2010 and 2017 meeting the stringent selection criteria. Content and thematic analysis showed low to medium degrees of innovation in most studies, with only 3 articles showing radically innovative, disruptive mobile learning practices. Illustrative examples are discussed across this 'innovation spectrum' and the notion of feasible innovation is proposed in the context of mobile learning in schools. The findings have implications for educators interested in designing and enacting effective innovative mobile learning practices, and researchers interested in the nature of innovation in mobile pedagogies.

1. Introduction

Mobile learning and mobile pedagogies have recently enjoyed an increase in interest regarding their benefits and constraints for teaching and learning. This increased interest is due to the ubiquity of mobile devices, a term covering netbooks, laptops, smartphones, tablets and two-in-one devices. Mobile learning is the term applied to learning with such devices, and falls under the umbrella term of 'ubiquitous learning', a term that indicates the ability to learn with the device at a time, place and manner of individual choice: "Ubiquitous learning refers to the process in which learners can obtain the needed resources anytime and anywhere to carry out learning" (Chen, Yu, & Chiang, 2017, p. 127). Ubiquitous learning or u-learning emphasises the contextualised and situated learning that is provided by use of mobile devices (Pegrum, Oakley, & Faulkner, 2013).

It is of interest to investigate how pedagogies might change as a result of using mobile devices for school learning. The term for pedagogies that use mobile devices as implicit parts of the learning design is 'mobile pedagogies'. The ability for learning to take place in a variety of places beyond the classroom and at a variety of times outside of the school timetable suggests a need to consider new teaching practices that embrace these opportunities (Schuck, Kearney, & Burden, 2017; Traxler, 2009). Mobile devices enable a whole suite of practices for school-aged students to engage with in out-of- school time. These practices include seamless interactions with people who may be geographically distant, sharing and creating of images and videos of common interest, and engaging in activities of interest to the user. The strong uptake of, and interest in, such practices by students indicates a gap between the way they

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are expected to operate in school and the way they engage out of school (Schuck, et al., 2017). In order to exploit student interest and capitalise on the characteristics and benefits of teaching and learning with mobile devices, teachers may need to review aspects of their current practices, schools may need to review their structures and policy makers may need to review the curriculum to be studied so that new ways of learning can be explored. At present, there is a general lack of understanding of how mobile devices are being used in education to develop new sorts of pedagogies that might enhance or disrupt the status quo. Given the opportunities to teach and learn differently that mobile devices offer (Schuck, et al., 2017), it is valuable to investigate how mobile devices are currently being used in new and innovative ways.

This article reports on a systematic literature review (SLR), which investigates whether and how mobile pedagogies are disrupting practice. The SLR is a component of a large-scale EU Erasmus Plus project (*Developing and Evaluating Innovative Mobile Pedagogies-DEIMP*), which aims to support school teachers and teacher educators to design and evaluate innovative, engaging and transformative mobile learning pedagogies that will improve student learning outcomes. The project involves an intensive professional learning aspect in which teachers are supported by research-based findings in their development of effective and innovative mobile pedagogies. A starting point for this project was an SLR which provided an analysis of the literature on mobile learning, to obtain a scan of the innovation and disruption that is reported in recent research on mobile pedagogies for school-aged learners. This article discusses the SLR that provides this scan. The research questions for this SLR are:

1. What do innovative and disruptive mobile pedagogies for school-aged learners look like?
2. To what extent do innovative mobile pedagogies disrupt structures and practices of teaching and learning for school-aged learners?

2. Background

There is much discussion about the potential of the use of mobile technologies to change schooling, teaching and learning (Joan, 2013; Kee & Samsudin, 2014; Schuck, et al. 2017). However, the reality is that pedagogies and schooling have not changed much since mobile technologies became commonplace for use in daily life. Incorporating mobile use into educational settings in defensible and effective ways is difficult, and expectations for radical change rarely take into account the complexity of schooling, the learning preferences of students and the interest and motivations of teachers (Jordan, 2011). For this reason, a SLR which considers research findings on what actually is occurring in teaching and learning of school-aged students is necessary. This article responds to this need.

Before discussing the design and implementation of the SLR, it is useful to clarify what is meant by innovative mobile pedagogies. Our definition of innovative mobile pedagogies, as used in this article, is of new pedagogies that are expressly designed to take advantage of mobile device characteristics to enable effective learning to occur in ways and contexts that could not occur without mobile devices. We base this definition on the discussion by Cochrane, Antonczak, Keegan, and Narayan (2014) of creative pedagogies and the need for pedagogy to move to heutagogy (student-determined context and content). These authors suggest that pedagogies should be created purposefully to exploit the characteristics of mobile devices that allow students to determine their own learning. Innovative practices are ones that are different from accepted and conventional practices, and include the effective use of new technologies (in this case mobile technologies) to promote 21st century skills of creativity, communication, collaboration and critical thinking (Burden, 2010; Schuck, Aubusson, Burden, & Brindley, 2018; P21, 2007).

Innovation suggests “new ideas or practices that are impactful and valuable to individuals or communities” (Kearney, Burden, & Schuck, 2019, p. 143). For this research we restrict the discussion to innovative pedagogies or new pedagogies that will contribute to effective learning in some way. This approach is comparable to previous measures and dimensions of innovation designed by Law, Chow and Yuen (2005) who identify six dimensions of innovation and three descriptors to measure these. We chose to dispense with their descriptor for traditional practices since all of the papers identified in our SLR were innovative in some form. We note that examples of innovative pedagogies lie on a continuum from ones that modify existing pedagogies, sometimes called sustaining (or incremental) innovations (Christensen, Horn, & Johnson, 2008; Cranmer & Lewin, 2017; Kearney, et al., 2019) to ones that create new practices, unlike those used previously. The latter are likely to be disruptive in nature, causing a change in paradigms, behaviours, and goals (Burden, Kearney, & Schuck, 2019), hence the term disruptive (or radical) innovations (Christensen et al., 2008; Cranmer & Lewin, 2017).

Sustaining innovations with mobile pedagogies are likely to use modified pedagogies that involve the use of mobile technologies to achieve existing curriculum goals (Christensen et al., 2008; Fenwick, 2016). They are deemed to be innovative because they employ new mobile technology-enhanced approaches which are of value for learning. Disruptive innovations are likely to exploit the characteristics of mobile devices such as portability, connectivity, user autonomy, and elasticity of time and place (Traxler, 2009) to influence designs of new pedagogies that impact on the learner in radically different ways from conventional practices. It is likely that effective introduction of such practices will result in heutagogy, allowing the learning to be learner-centred, reflective and collaborative (Cochrane et al., 2014). Such disruptive, technology-mediated approaches enable the nature of the learning to be significantly different from other learning experiences (Selwyn, 2017). Such disruption might include a change in the roles of the teacher and student, the relationship between them, and possibly the nature of the curriculum and school itself (Burden, et al., 2019).

It is clear that enacting any innovative mobile pedagogy is likely to be challenging to teachers and students, bound by the curriculum, place and time constraints of present-day schooling, including some structures and practices that date back to the industrial age (Schuck, et al., 2017; Papert, 2004). For the innovation to be a disruptive one is even more challenging (Kampylis et al., 2013). This article sets out to investigate what innovative or disruptive practices exist in the mobile pedagogy research literature and to understand what lessons can be learned from the existing research on innovative mobile pedagogies. While there has been much

research on mobile learning, and extensive discussion on innovation, up to this point, there has been little or no research on what constitutes innovative or disruptive mobile learning, particularly for school-aged learners. The mapping in this article provides much-needed and original insights into this lacuna.

3. Research design

As noted above, the SLR is a component of a larger research project which seeks to support teachers in their design and use of innovative mobile pedagogies. As a first step, the authors sought to investigate what innovative mobile pedagogies might look like. This took the form of an SLR which investigated the following research questions:

The research questions for this SLR are:

1. What do innovative and disruptive mobile pedagogies for school-aged learners look like?
2. To what extent do innovative mobile pedagogies disrupt structures and practices of teaching and learning for school-aged learners?

3.1. Search strategy

We took the following steps in order to thoroughly search for the relevant studies:

1. Derived key search terms arising from the Research Questions;
2. Identified possible replacement terms for our key search terms, as used in published literature;
3. Constructed a search string from the resulting terms, connected using Boolean operators;
4. Selected a range of online databases for searching;
5. The string was applied on abstracts;
6. The searches were open for dates from 2010 to 2017;
7. Managed the search findings using an annotation program.

Based on the research question, three major search terms were derived, i.e. mobile learning, transformation, school-aged learners. From these major search terms, replacement terms were identified (see Appendix B). The following search string was then used to search on abstracts of relevant papers:

(((mobile pedagog*) OR (mobile learn*) OR (mobile supported learn*) OR (mobile enhanced learn*) OR (mobile supported teach*) OR (mobile enhanced teach*) OR (mobile supported pedagog*) OR (mobile enhanced pedagog*) OR (mobile didactics) OR (mobile teach*) OR (mobile technolog*) OR (mobile digital technolog*) OR (mobile educational technolog*) OR (mobile device) OR (mlearn*) OR (m-learn*) OR (handheld) OR (handhelds) OR (tablet) OR (tablets) OR (ipad*) OR (android) OR (app) OR (apps) OR (app-based) OR (phablet) OR (smartphone)) AND ((disrupt*) OR (transform*) OR (innovat*) OR (re-vision*) OR (reimag*) OR (re-imag*) OR (renew) OR (re-new) OR (redefin*) OR (re-defin*) OR (future-oriented) OR (future-focus*) OR (future-proof) OR (paradigm shift) OR (paradigm change) OR (cutting-edge) OR (contemporary) OR (progressive) OR (pioneer*) OR (frontier) OR (ground-breaking) OR (groundbreaking) OR (change* pedagog*) OR (enhance* pedagog*) OR (change* teaching approach*) OR (enhance* teaching approach*) OR (change* teaching strateg*) OR (enhance* teaching strateg*) OR (change* learning practice*) OR (enhance* learning practice*) OR (change* learning approach*) OR (enhance* learning approach*) OR (emerging pedagog*) OR (new pedagog*) OR (emerging practice*) OR (new practice*) OR (best-practice*) OR (exemplary-practice*) OR (emerging teaching approach) OR (new teaching approach) OR (emerging teaching strateg*) OR (new teaching strateg*) OR (emerging learning practice*) OR (new learning practice*) OR (emerging learning approach) OR (new learning approach)) AND ((school*) OR (secondary education) OR (primary education) OR (elementary education) OR (secondary-age*) OR (primary-age*) OR (elementary-age*) OR (K-12) OR (P-12) OR (7-12) OR (K-6) OR (P-6) OR (7-10) OR (K12) OR (K6) OR (P12) OR (P6) OR (youth) OR (teen*) OR (adolescen*) OR (child*) OR (tween)))

The string was amended as necessary and applied to different online databases to ensure that relevant studies were not missed. The following databases were selected:

- Education Research Complete (https://www.ebsco.com/products/research-databases/education-research-complete)
- ERIC (https://eric.ed.gov)
- Gale (https://www.gale.com/databases)
- Informit A + Education (https://www.informit.org/informit-education)
- ProQuest (http://www.proquest.com)
- Sage Journals (http://online.sagepub.com)
- Scopus (https://www.elsevier.com/solutions/scopus)
- Web of Science (https://clarivate.com/products/web-of-science)

The references provided in the following published systematic reviews were also scanned to find any study that might have been missed (Chee, Yahaya, Ibrahim & Noor, 2017; Crompton, Burke, Gregory, & Gräbe, 2016; Parsons, 2014; Pereira & Rodrigues, 2013; Sung, Chang, & Liu, 2016). Those papers that appeared to be eligible for consideration were treated with the same study selection criteria set for the primary search selection.

Table 1
Search and selection summary.

Digital library	Number of articles
Education Research Complete	108
ERIC	93
Gale	12
Informit A + Education	99
ProQuest	75
Sage Journals	30
Scopus	215
Web of Science	204
References from recent reviews	6
TOTAL	842
TOTAL when duplicates removed and journal impact factor applied	244
TOTAL after exclusion due to poor database search performance	208

3.2. Study selection

Once all the results were obtained from the online databases, duplicate citations were discarded. The quality of the publications was ensured by checking the SCImago journal ranking (SJR) and excluding papers from journals that were not placed in the top two quartiles. Any irrelevant papers that were retrieved due to poor performance of search engines were excluded by reading their titles and abstracts. The initial search and selection process is summarised in Table 1.

The included papers were given an identification number (1–208). If more than one paper was subsequently found to be describing results from the same empirical study, the papers were treated as one study and given one identification number.

Following the initial search and selection process, the remaining papers were filtered with the criteria described in Table 2. The selection process was carried out by the research team using a rigorous procedure. Pairs of project team members applied the selection criteria to the abstracts of all papers included in the search results. Issues related to selection of a paper were resolved through inter-researcher discussions at team meetings. Any remaining questions were resolved by reading the full text of the paper. Different team members randomly checked among the results to reduce selection bias.

Following this reading of abstracts, 72 papers had passed through all inclusion criteria checks and were made available for full text review. The papers were then assessed for inclusion by having pairs of researchers read the full text to determine whether:

1. Convincing evidence was presented and methodology was rigourous, that is the quality was assessed as high (see section 3.3 below);
2. The paper showed evidence-based benefits to learners (affective, cognitive etc.);
3. Pedagogical strategies/interventions were identified;
4. A pedagogical innovation was presented.

If any of these criteria was not met, the paper was excluded. Any issues were resolved through discussions involving the whole team.

3.3. Study quality assessment and data extractions

The next step was to ensure the quality of the included papers. We assessed the quality of each paper on following criteria:

1. Publication outlet: The SJR value of the journal was assessed to rank the included articles;
2. Impact: Google scholar or Scopus citation count along with the year of publication was used to assess the impact of the study;
3. Research methodology. Clear research aims, research questions, data collection methodology, data analysis and results.

Table 2
Study selection criteria.

Inclusion Criteria	Exclusion Criteria
Published in English	Not empirical (book review, opinion, editorial, conceptual work, framework or thesis)
Published from 2010 to 2017	The study does not provide sufficient details of empirical research design and data analysis
The SCImago journal ranking (SJR) is in the top two quartiles	Pedagogy is not innovative
Targets school-aged learners	
Follows empirical research methods	
Is focused on innovative pedagogies and mobile technologies	

The final quality assessment outputs were peer reviewed by the team members to ensure the inclusion of best evidence. At the conclusion of this process there were 57 articles selected as being suitable for inclusion in this systematic review (see Appendix A for full list of 57 articles).

Three types of data extractions were carried out on this final set of articles:

1. General attributes: The general attributes included title, year of publication, authors, publication outlet, geographical location (location in which the study was conducted);
2. Context: The context and the details of how the study was implemented;
3. Findings: The information required to answer the research questions, i.e. the evidence presented of innovative pedagogies and benefit to learners.

3.4. Criteria for innovative studies

Having identified the 57 articles as showing innovation in some way and meeting all the required criteria, the next step was to determine the level of innovation or disruption that each article presented. This was assessed by investigating the level of innovation of each of the following factors or elements of learning. These four factors were derived from the discussion of innovation suggested by the literature:

A. The purpose of learning (e.g. the curriculum; learning objectives, etc) and/or the nature of the task/activity and/or the embeddedness of mobile learning;
B. The context of the learning (e.g. the place or time in which learning is undertaken; pedagogical practices; mode);
C. The role of the teacher/educators and their relationship with the students (didactic; involving communities other than school);
D. The role of the learner (agency, passive).

These four factors are aligned to the six dimensions of innovation with ICT used by Law, et al. (2005). The relationship between our factors and Law et al.'s dimensions are outlined in Table 3.

To keep the focus on mobile pedagogical innovation, we chose not to use Law et al.'s dimension titled: 'nature and sophistication of the ICT used'. Instead, our first factor (A) addressed the effectiveness of use of the mobile technologies described in the innovation (ie. could the pedagogical innovation be implemented without the mobile technology?). Also, our factors A and B captured the critical aspect of how well the innovation exploited the flexibility of mobile learning contexts.

Our initial overview of the final data set identified nine articles that appeared at first glance to be most disruptive. However, we felt there was a need to differentiate the papers at a more granular level and consequently we started the process of scoring each paper according to the presence of the four factors above. Each article was scored on: task/activity; context; teacher-student relationship; student agency. For each factor a score of 1–3 was given: 1 for low innovation on that factor, 2 for medium innovation, 3 for high innovation. Given that the final set of 57 articles all displayed some innovation, all papers scored at least one for each factor. Therefore, the expected total score for each article across all four factors ranged from 4 to 12. Using these total scores, we were able to classify each paper as follows: *Low Innovation: (total score of) 4–6; Medium Innovation: 7–9; High Innovation: 10–12.*

The first nine articles (those originally identified as most disruptive) were scored collaboratively by three members of the team with discussion about each factor. A score for each of these nine articles was arrived at by mutual consent after discussion. Once the nine articles had been scored collectively, the remaining 48 articles were divided into three groups and each researcher then scored a set of articles independently. The total score for each article comprised a sum of the scores the article had achieved on each of the four factors.

A table of average scores was developed - see Table 4 below.

As expected, the average of scores for the first nine papers was higher than the averages for the other three groups as these nine papers had initially been identified as most disruptive. Within the three groups scored individually by the researchers, it appeared that researcher 1 was not aligned with the other two researchers in scores on Student Agency, as the score for this criterion was statistically different from the other two researchers' scores. Similarly, researcher 3 seemed out of step regarding the nature of the task or activity. The researchers discussed again their criteria and how they had arrived at their individual scores and ensured that they had a shared understanding. Researcher 1 and researcher 3 agreed to review their allotted articles with particular attention to

Table 3
Alignment of Law et al.'s (2005) six dimensions of innovation with the four factors used in our study.

Law et al.'s (2005) dimensions of innovation	Alignment to our factors
Intended curriculum goals of the innovative practices	A
Pedagogical role(s) of the teachers;	C
Role(s) of the students;	D
Nature and sophistication of the ICT used	A
Multidimensional learning outcomes exhibited	A
Connectedness of the classroom.	A and B

Table 4
Initial scores of individual researchers.

Researchers (Paper id. numbers)	Task/activity	Context of the learning (e.g. time/ place/space)	Relationship between teacher/ student	Student agency	Total
All 3 researchers (Nine Papers: Nos. 2, 13, 28, 55, 56, 82, 109, 114, 141)	1.8	2.1	2	2.1	7.4
Researcher 1 (16 Papers: Nos. 10, 12, 14, 15, 21, 22, 26, 31, 39, 42, 44, 45, 47, 48, 51, 60)	1.7	1.3	1.1	*1.1*	5.1
Researcher 2 (15 Papers: Nos. 63, 76, 78, 79, 86, 88, 89, 90, 92, 93, 97, 101, 102, 110, 119)	1.8	1.5	1.4	1.9	6.5
Researcher 3 (17 Papers: Nos. 120, 123, 131, 135, 142, 146, 158, 159, 165, 172, 173, 176, 179, 182, 183, 186, 198)	*1.3*	1.5	1.3	1.9	6.1
Overall Averages (All 57 papers)	1.6	1.5	1.3	1.7	6.1

Table 5
Final researcher scores on innovation.

Researchers (Paper id. numbers)	Task/activity	Context of the learning (e.g. time/ place/space)	Relationship between teacher/ student	Student agency	Total
All 3 researchers (Nine Papers: Nos. 2, 13, 28, 55, 56, 82, 109, 114, 141)	1.8	2.1	2	2.1	7.4
Researcher 1 (16 Papers: Nos. 10, 12, 14, 15, 21, 22, 26, 31, 39, 42, 44, 45, 47, 48, 51, 60)	1.8	1.3	1.2	*1.8*	6.0
Researcher 2 (15 Papers: Nos. 63, 76, 78, 79, 86, 88, 89, 90, 92, 93, 97, 101, 102, 110, 119)	1.8	1.5	1.4	1.9	6.5
Researcher 3 (17 Papers: Nos. 120, 123, 131, 135, 142, 146, 158, 159, 165, 172, 173, 176, 179, 182, 183, 186, 198)	*1.9*	1.5	1.3	1.9	6.6
Overall Averages (All 57 papers)	1.8	1.5	1.4	1.9	6.5

Table 6
Geographical distribution of papers.

Region	Number of papers
South-east Asia (Taiwan (14), Singapore (8), South Korea, Hong Kong)	25
Europe (Italy, Spain, France, Germany, Ireland, Sweden, The Netherlands, Cyprus, UK)	15
North America (USA (6), Canada)	8
Australia	4
Middle East (Israel)	3
South America (Chile, Trinidad and Tobago)	2

their scoring of the category in which they differed significantly from the other researchers. This resulted in a revised set of scores that were better aligned - see Table 5.

4. Findings

As noted, following the selection and exclusion process described above, 57 papers were identified as meeting the full criteria for this SLR. The following tables provide detail concerning characteristics of the authors or research studies reported.

4.1. Details of studies

An analysis of background data associated with the final 57 articles revealed information about the age of learners in the studies, learning settings used, discipline foci and study contexts. Most studies were implemented in South-east Asia and Europe, as shown in Table 6 below.

Forty-four percent of all the papers that were identified in this SLR featured studies located in South-east Asia with Taiwan and Singapore accounting for 25% and 14% respectively. Europe, the next largest grouping after South-east Asia, only accounts for 26% of the total papers and no single European country had more than 3 papers in the SLR. The remaining regions of the world account for only 17 of the 57 papers (30%).

Table 7reports on the discipline focus of the activities reported. There were a wide range of disciplines represented in the final set of 57 papers. In agreement with previous SLRs in mobile learning (Bano, Zowghi, Kearney, Schuck, & Aubusson, 2018; Liu et al., 2014), Science was the most common discipline focus. This reflects the strong interest that science and STEM teachers and researchers have shown towards mobile learning since its inception.

The majority of studies focused on upper primary/elementary aged learners, followed by secondary school students, particularly middle school aged learners. See Table 8.

It is worth noting that the articles discussed interventions using mobile learning across primary and secondary school. Most were located in the primary school but junior secondary school studies were also well represented. Studies that went across school levels were less common, but this may have been a result of the emphasis on 'school-aged' in the search strings.

Given that a key characteristic of mobile device use is the ability to use them in any location or context, we were also interested in where the activities identified in the 57 articles took place. Fig. 1 indicates the settings of the reported activities and characterises them as formal, multiple, semi-formal or informal. We use the definitions of these settings proposed by Bano, et al. (2018, p.48) "Formal settings are defined as traditional school-based learning spaces such as classrooms and laboratories; semi-formal settings are out-of-classroom contexts usually selected by a teacher, such as school playgrounds, museums and field trips; and informal settings are recreational or everyday spaces generally chosen by learners, such as trains, cafes and parks. Finally, the multiple settings

Table 7
Discipline focus of papers.

Discipline focus	Number of papers
Science	20
Social Science	9
Languages	4
Literacy	4
Maths	4
Visual Arts	4
Generic (e.g. focus on reflective practices)	4
Geography	2
Cross-discipline (range of subjects)	2
Health/Physical Education (PE)	2
English	1
Environmental studies	1

Table 8
Background data on learners' age groups.

Age of learners	Number of papers
6–12	31
13–18	22
6–18	3
Life-long	1

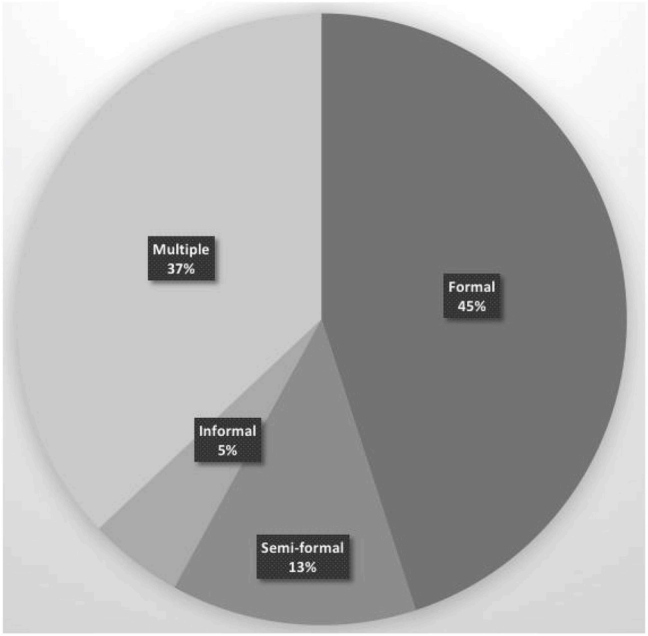

Fig. 1. Contexts of study activities.

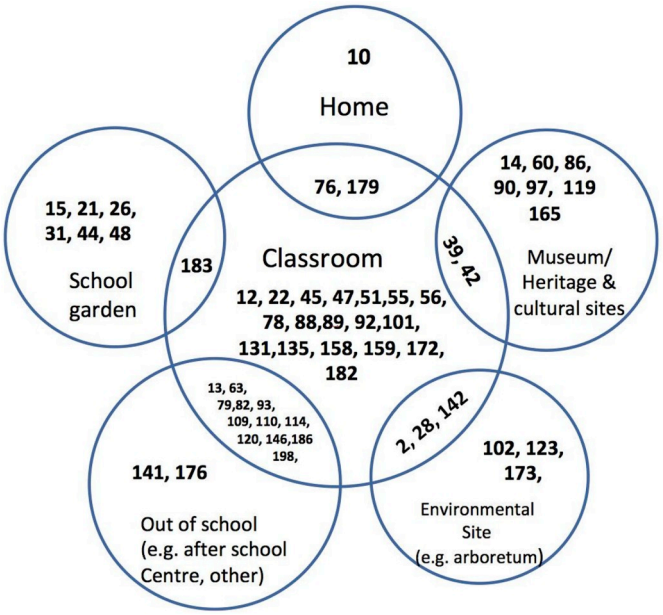

Fig. 2. Contexts of activities from 57 SLR articles.

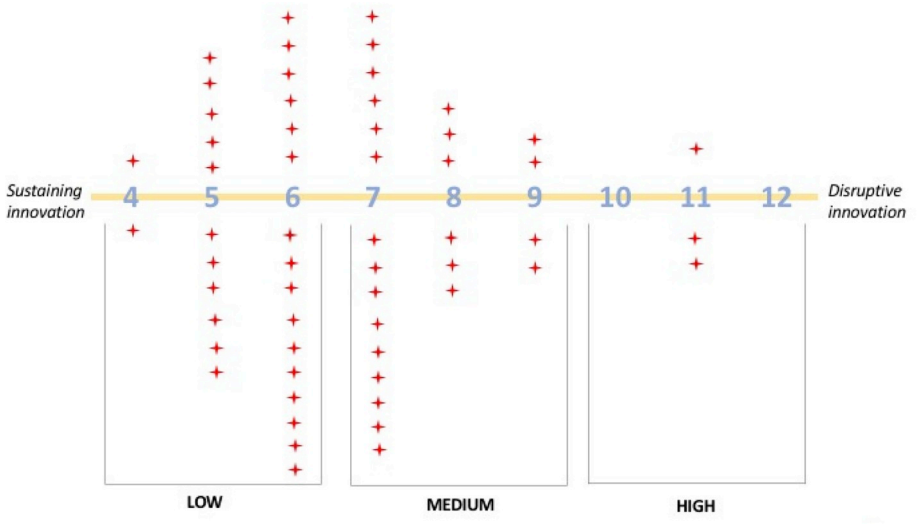

Fig. 3. Innovation Continuum - breakdown of all 57 papers according to level of innovation.

category is defined as participants in the study using their mobile devices in more than one setting, across at least two (physical) learning spaces." Overall, 45% of papers described use of formal settings, 13% semi-formal settings, 5% used informal; settings and 37% used multiple settings, as shown in Fig. 1.

It is worth noting that although mobile learning has a major characteristic of portability, the majority of articles described innovations that took place in the classroom or school grounds, as shown in Fig. 2.

4.2. Extent of disruption

As noted in the methodology, each article was scored on four factors: task/activity; context; teacher-student relationship; student agency. Given that the final set of 57 articles all displayed some innovation, all papers scored at least one in each criteria. Therefore, the expected total score for each article across all four factors ranged from 4 to 12. Using these total scores, we were able to classify each paper as follows: *Low Innovation: (total score of) 4–6; Medium Innovation: 7–9; High Innovation: 10–12.*

Based on the total scores for each of the final set of 57 papers, a large number (29) were classified as 'sustaining innovations' or 'low' on the innovation spectrum. Twenty-five of the papers were identified as being more disruptive innovations (labelled as medium on the innovation spectrum) and just three were classified as radically disruptive innovations (high on the innovation spectrum), as shown in Fig. 3 below.

The average score for all 57 papers was 6.5 (see Table 5), sitting on the borderline between the low and medium innovation categories. An elaboration of these three categories and lists of associated papers are outlined in Table 9.

None of the 29 papers in the 'low' category scored a 3 (high innovation) for any of the four criteria and all scored 1 (low innovation) for at least two criteria. At the lowest end of the continuum, 13 papers scored three or more 1's in the four categories, and two papers scored all 1's.

On examination of the papers placed in the medium category, it was found that they had at most one criterion receiving a score of 1. There were a total of 17 papers in this category that received a score of 1 in one criterion. Six of the 25 articles in this category

Table 9
Waypoints along the innovation spectrum.

Low (29 papers) Sustaining innovation	Medium (25 papers)	High (3 papers) Disruptive innovation
The innovation: - is adapted from existing practices or approaches to make them more effective or efficient, but not to radically change them; - adapts existing pedagogies, practices or structures to make them more efficient/ effective	The innovation modified or added something new but this did not in itself fundamentally challenge or alter the underlying approaches, purposes, structures or practices	The innovation: - changes the existing paradigm. It creates new educational purposes or processes and challenges and fundamentally alters existing approaches and practices such as the relationship between teachers and students or the nature of the curriculum - enables learning to occur in ways and contexts that could not occur without a mobile device.
Papers: 12, 14, 15, 21, 26, 31,42, 44, 45, 48, 55, 56, 60, 63, 76, 78, 79, 88, 89, 90, 92, 131, 135, 158,159, 165, 172,182,183	Papers: 10, 13, 22, 39, 47, 51, 82, 86, 93, 97, 101, 102, 109, 110, 114, 119, 120, 123, 142, 146, 173, 176, 179, 186, 198	Papers: 2, 28, 141

scored a 3 or a high innovation for just one criterion, and half of these high innovation scores were for the Task/Activity factor. The rest of the scores fell into the medium innovation category.

The three papers identified as being in the high category had a maximum of just one score of 2 across the four criteria, with the rest all receiving the highest score of 3.

5. Discussion

This SLR provides evidence-based insights into the nature of innovation and how it occurs in practice. Such insights are noted to be critically needed in the educational technology field (Cuban, 1986; Cuban, Kirkpatrick, & Peck, 2001), or more specifically, the mobile learning field (Milrad et al., 2013; Rushby, 2012) in contrast to the anecdotal, often faddish claims that are made (Selwyn, 2010). Overall, our SLR sheds light on how the use of mobile technologies might leverage innovative pedagogies to support school-aged learning. The findings also align with Cochrane et al.'s (2014) arguments for m-learning approaches to become more heutagogical, supporting more learner-centred, reflective and collaborative processes.

5.1. The innovation continuum

We reiterate that all 57 articles included in this SLR explored aspects of innovative m-learning practices that made an evidence-based impact on teaching and learning. Data revealed that school-aged students' use of mobile devices can leverage new and valuable ways of learning, for example, in and across formal and informal contexts (e.g. papers 2, 10, 28, 141) in a range of disciplines and school-aged groups. Data also suggested that use of mobile devices can support teaching approaches emphasising collaboration and social aspects of learning (e.g. 13, 28, 141), inquiry (e.g. 2, 82), situatedness and contextualised learning (28), and a few studies illuminated new ways of thinking about teacher roles (e.g. 2, 13, 28, 102) and student agency (2, 13, 28, 102) that might disrupt traditional approaches.

An analysis of researchers' ratings of innovation across the whole set of 57 papers (see Table 5) revealed that the strongest aspect of innovation in these studies was student agency (average = 1.9 out of 3 for this factor). Given that personalised learning and ownership are frequently reported as benefits of mobile learning (Kearney, Schuck, Burden, & Aubusson, 2012), this finding was perhaps unsurprising. However, despite the aforementioned few studies showing new teacher roles, overall the studies in this SLR lacked disruptive elements to the traditional teacher-student relationship (average = 1.4 for this factor). There was an overall lack of studies where alternative roles of teachers (other than guides, information providers etc.) were investigated, including a lack of research into potential roles of other partners such as peers, family and community members in facilitating students' learning across a range of contexts.

In reviewing the papers in this SLR we conclude that innovation in the context of mobile pedagogies is a multifaceted construct that encompasses many different forms. As shown in Fig. 3, these include a small number of studies that report highly disruptive mobile pedagogies but far more that we classify as medium or low in innovation. In the following subsections, we illustrate the range and variation of innovative mobile pedagogies using one paper from each of the three categories (high, medium and low), and describe these using the four criteria which were used to rank each paper (i.e. task/activity; context; teacher-student relationship; student agency).

5.1.1. Radical disruptions: high on the innovation spectrum

Of the 57 papers, only three (see papers 2, 28, 141) focused on practices that were assessed by the research team as demonstrating high levels of mobile pedagogical innovation, containing pedagogical elements that could potentially disrupt traditional practices (see Table 9 above). All three papers report how students undertook tasks and activities that would have been demanding or even impossible without mobile technologies.

Involving the community in project-based learning was a strong theme in all three of these studies rated as high in innovation. This approach potentially disrupts traditional notions of teachers and students interacting in bounded school systems, artificially separated from other sections of society. Students in these three studies either used community members as resources, such as the family members consulted in the inquiry projects described in paper 2; or participated in projects that aimed to make a community contribution (Denning, 2004; Fenwick, 2016; Lindfors & Hilmola, 2016). The studies were all evaluated by the research team as being of high value to the community. For example, the creation of publicly available location-based interactive learning objects (LILOs) in paper 28, and collection of data in the health promotion project in paper 141, evidently made valuable contributions to local virtual and physical communities.

Another strong theme in all three of these high innovation studies was students' high levels of autonomy in relation to where, when and at what pace they implemented these projects, what apps they used and how they used them. These studies reported on a radical shift in student agency well beyond traditional boundaries imposed on students in classroom-based learning. Working within broad discipline parameters, students exercised high levels of control over project topics and associated learning objectives, and enjoyed high degrees of agency in the design process of their projects, as they co-designed apps (paper 141) and LILOs (paper 28).

5.1.1.1. Illustration of radical disruption. The Barak and Ziv (2013) study (paper 28) investigated Year 9 students' use of a web-based platform called Wandering that was used to facilitate outdoor, interactive learning in their environmental studies. Students used the program to design and create their own (LILOs: short, re-useable packages that included an objective, a learning activity and peer assessment. Learning was enhanced through students searching for information, creating their LILO, and then sharing it with the

community using social media. Findings indicated high motivation among students not only for completing their school assignment, but also for contributing to the community.

The student activities in this study represented a disruption to traditional notions of curriculum. LILOs are traditionally created by teachers who design the learning activity. In contrast, in this study the authors described a process where students created their own learning objects using a m-learning platform called 'Wandering' that is open and democratic. Therefore, student-generated LILO content was eventually blended with more formal teacher or expert-created content, to become part of the whole Wandering learning environment for use in subsequent years.

Students learned across the school and the local environment as they searched for ideas and content for their LILOs, and in this way, the activities exploited mobile learning across rich contexts. Unlike many of the studies in our SLR, this study described initiatives that were rated as high in innovation in the areas of student-teacher relationships and student agency. The authors of the study emphasized the teachers' guiding, supervisory roles, and later discussed the critical notion of teachers *'releasing control'* to encourage students' independent learning, allowing them "to explore, make mistakes, and learn from them; all this, while they are out of the classrooms walls" (p. 169).

5.1.2. Medium innovations: medium on the innovation spectrum

Twenty-five of the 57 articles were classified as medium on the innovation continuum (see Fig. 3) and are listed above in Table 9. Six of these papers scored highly (3) on one of the four criterion (see papers 10, 13, 82, 97, 102, 198) but these were isolated scores and the vast majority of papers in this category scored medium (2) for most of the four criteria. Taken collectively, none of these studies challenged the status quo or underlying structures and practices of education in the same way as those described as 'disruptive innovations' above. The paper below is representative of those described as 'medium innovations'.

5.1.2.1. Illustration of medium innovation. The Looi et al. (2011) study (paper 146) explores how teachers used portable technologies to mobilise the primary school science curriculum by identifying those features or affordances of mobile devices that are particularly suited to supporting inquiry based learning, both inside and outside the classroom. Over a period of 21 weeks, grade 3 students in a Singaporean primary school used mobile devices throughout the science curriculum to investigate a series of scientific challenges with a focus on 'seamless activities' that crossed the boundaries between formal and informal learning contexts. Teachers worked closely with researchers to design tasks that enabled students to undertake more personalised learning pathways using the mobile device as a hub to collect, store, edit and analyse data, before sharing it with their peers and teachers. These tasks were highly student-centred, inquiry-based and collaborative in nature. The teachers aimed to design tasks that were highly authentic and meaningful for students such as a visit to a biotic drink factory where students learned about the presence of good bacteria and how it travels through their digestive systems. Students were often shown a scientific experiment in school - which they frequently filmed using their mobile devices - and were then tasked with devising and undertaking a similar but different experiment at home with the help of their parents, again incorporating the mobile device.

Findings from the study indicated that students were more engaged and more able to conduct their own research. They used the mobile devices extensively to produce artefacts to demonstrate their scientific understanding and to share and reflect on these with other students. Students were more self directed than previously, especially in working to teach their own parents about different scientific concepts. Significantly, students were more collaborative and prepared to share their ideas and reflections with peers which altered the culture of science lessons.

Despite the importance placed by the teachers and researchers in designing authentic, student centred tasks and activities, none of these were categorised as significantly disruptive and most of them followed traditional classroom practices. Whilst the mobile devices played a significant part in supporting students to undertake these tasks (e.g. video recording the experiments they undertook at home with their parents) they were not indispensable and most of the tasks/activities could have been undertaken with more conventional tools. The context and setting of the activity, however, did challenge conventional patterns of scientific inquiry in primary schools which tends to be restricted to the classroom. In this study students were encouraged to use the mobile device in the home setting and during field tasks and hence this scored more highly. However, unlike the disruptive innovation illustration described previously, in which the relationship between teachers and students was skewed heavily towards the latter, this study was more typical of the medium scored papers in which teachers made most of the decisions about the overarching nature and design of learning tasks. Students were able to exercise some autonomy in how they used the mobile device to undertake these tasks (e.g. in how to record their own progress) but not the task itself. This and the other features described in this illustration were typical of those papers we categorised as demonstrating medium levels of innovation.

5.1.3. Sustaining innovations: low on the innovation spectrum

The single largest group of papers (29) was ranked as low on the innovation spectrum (see Fig. 3). Although the lowest ranked papers in this group scored only four (a score of one in each of the four categories) it should be remembered that these articles were all included in the final set of 57 articles deemed to be innovative and therefore they all displayed innovative features according to our selection criteria. The innovation noted in these articles would be regarded as sustaining or incremental innovation, the level of innovation that has been argued to be most feasible for teachers to adopt (Cranmer & Lewin, 2017; Kampylis et al., 2013; OECD, 2008; Rogers, 2003). Across the group as a whole, the degree of innovation was judged to be less disruptive than in the other two categories but it was still innovative. So for example in 21 of the 29 papers in this category, student agency was ranked as medium (score of 2) (see papers 12, 14, 15, 21, 31, 34, 48,56,63, 76, 78, 88, 89, 92, 131, 135, 158, 159,172, 182, 183). This is a remarkably high score given that recurrent studies in the m-learning research literature highlight the need for teachers to consider more carefully

how they can empower, rather than disempower, their students by granting them more opportunities to use their mobile device to exercise greater autonomy and make more choices (Kearney, Burden, & Rai, 2015). This point is highlighted in the illustrative paper below.

5.1.3.1. Illustration of sustaining innovation. As an example of innovation situated in the middle of the low innovation category, we have selected paper 159 (Smith & Santori, 2015) which investigates the use of iPads in two middle schools in the USA. The study collected data using observations in six different classrooms across four content areas which included science, social studies, mathematics and language arts. Using portraiture methodology, the authors constructed a composite narrative to illustrate the typical usage of iPads in a science context and in doing so they identified five emergent themes: differentiation; learner independence and agency; dynamic teaching and learning; and interactive engagement and motivation by learners. Using the four criteria described in this paper we placed this study at the low end of innovation. All of the tasks and activities that were used by the students were designed entirely by the teachers and many of them resembled traditional e-learning activities that might otherwise have been undertaken on a tethered computer, for example, following predetermined hyperlinks to locate resources. The use of e-Books, prepared by the teachers, was however an innovation and was used to avoid the need for worksheets or separate digital files. Although the iPads offered significant opportunities for learning in and across different spaces, mobility was not reported as being an important aspect of the experience. As a result the context for learning criterion also scored low on the innovation spectrum since students only used the iPads inside the classroom and were given no opportunities to use them at home or anywhere else on the school site. This was noted as a problem by the teachers in the study but rather than extending the use of the iPad outside of the classroom the school sought other ways for students to continue their work such as posting work on the virtual learning environment for those students who had internet access at home.

The relationship between teachers and students does not appear to been fundamentally disrupted with the introduction of the iPads in this study although the teachers went to considerable lengths to devise individual learning pathways for their students which enabled them to enjoy significant autonomy and choice in how they tackled and completed a task, if not the nature of the task itself. Some students chose to represent their ideas and findings in the form of an iBook whilst others chose to use more concrete approaches such as LEGO. Therefore although the teacher/student relationship was deemed to be fairly traditional, the score for student agency was rated as medium.

5.2. Feasible mobile pedagogical innovations for school-aged learners

Given the well-reported tendency of school teachers to replicate traditional practices when teaching with mobile devices (Burden & Kearney, 2016), fifty-seven articles was a surprisingly large number showing some level of innovative mobile pedagogies in the reported initiatives. As discussed in the previous section, a large number of these papers (29 from 57 papers) in this SLR were rated by the research team as displaying innovation at the 'low' end of the continuum— reporting on mobile learning initiatives that could be described as more 'sustaining innovations', that adapt existing approaches (Christensen et al., 2008; Fenwick, 2016) and modify established practices (Christensen, 1997). In some ways, the lack of disruption evident in this SLR is not surprising, given that a gradual, incremental approach is often regarded as a more pragmatic approach for schools (Law, 2003; Zhao, Pugh, Sheldon, & Byers, 2002). Indeed, our findings could be explained using a similar thesis to Jordan (2011), Selwyn (2017) and Papert (2004): we should not expect radical innovation given the current constraining parameters of schools themselves, including an over-emphasis on high stakes testing, rigid timetables and constrained learning spaces and out-moded curriculum content (in some institutions, akin to 19th century models of schooling).

Given this general lag in development of disruptive mobile pedagogies, we suggest that future m-learning studies of innovative practices with school-aged students should go beyond sustaining innovations to ones that focus on some elements of disruption, similar to the some of the pioneering studies identified in this SLR that were ranked as 'medium' or 'high' in disruption. However, given the previously discussed inertia to change and the constraining parameters of schools, we should not expect all stakeholders in school education to embrace radical innovations as this expectation is unrealistic in the current educational climate and unlikely to succeed (Cranmer & Lewin, 2017). Rather we suggest that researchers focus on studies of 'feasible' innovation, somewhere between conservative and radical, and view innovation as being on a continuum. We therefore argue that an important aspect of a innovative m-learning practice for school-aged learners is its feasibility and likelihood to succeed and be scalable.

For example, the Kim, Suh and Song (2015) study (paper #101) from this SLR investigated Year 5 children's use of apps as a tool to support their own design-based learning activities in science, albeit in a formal classroom setting. Rated at the lower end of 'medium' on our 'innovation continuum' (see Table 9), the study showed some aspects of innovation that could be considered feasible in primary/elementary school education. The way that children in this study used their devices to support their open-ended, inquiry-based activities could be perceived as somewhat disruptive, mindful of the ways that mobile devices have more commonly been used to support more traditional, highly scaffolded 'recipe' approaches to inquiry in primary science education. The activities in this study enabled children's input into the design and afforded students' flexibility in the way they used their chosen apps to collaboratively document their design processes, multimodally record notes, make accurate measurements, record and analyse data and share reports. Also, in contrast to traditional cooperative learning approaches in primary education, the study reported on numerous emergent team behaviours that were not directed by the teacher, for example, the allocation of roles within teams by peers. However, the classroom-based inquiry lessons were rated as 'low' for context, with little disruption to traditional notions of place and time. This lack of disruption possibly assisted the development of other innovative aspects and the overall feasible nature of these innovations. For example, being in the same learning space (at the same time) as their peers and the teacher might have had a positive benefit on some of the inter-team and student-teacher interactions.

6. Limitations

We may not have captured all papers in the area, due to limited numbers of synonyms and publication date constraints. We may also have missed papers that detailed high quality research because the journal in which they were published did not meet our quality selection criteria. Also, to manage the large numbers of papers that emerged from the original search (208 papers), we did not include recently published scholarly conference papers in our search. However, the 57 papers in our final selection provided a comprehensive and trustworthy set of data on innovation in mobile learning.

We recognise that interpretations of innovation, and the extent to which a practice is new or impactful, ultimately depends on one's perception and context (Caldwell, 2018). To address this issue before analysing the data in this study, the research team held numerous (10–15) lengthy discussions informed by relevant literature to reach consensus on our collective understanding of key concepts relevant to this paper, such as 'innovation' and 'disruption', and 'traditional' and 'progressive' practices. These discussions, as well as inter-researcher checking procedures, helped avoid inevitable bias in relation to researchers' judgements when selecting and rating papers in this SLR. However, we acknowledge that these ratings were ultimately subjective and lacked input from other voices such as those of teachers, school leaders and especially learners themselves. Hence, future studies could be informed by other stakeholders' perceptions of notions such as 'innovation' and 'disruption'.

7. Future studies

Given the importance of the debate on use of mobile pedagogies currently occurring, future studies should examine what sort of mobile learning activities are feasible under the constraints of current schooling systems. We also encourage further studies on what other 'feasible innovative mobile pedagogies' might look like, across a range of contexts.

As noted above, the voice of learners is largely lacking in this SLR and it would be beneficial to know what learners' views and concerns are. Additionally, a SLR that focused on the seamless nature of learning facilitated by mobile learning would be interesting. There was a major emphasis in the SLR on formal contexts (see Figs. 1 and 2), with few studies emphasising mobile learning across contextual boundaries. It is likely that the number of such studies will increase in the future and a SLR that captures such activities would provide rich information on an important affordance of mobile learning.

Finally, the innovative characteristics of activities encouraged by mobile learning lead to a questioning of current curricula, their structures and related high stakes testing regimes. While such questioning is only relevant at the disruptive side of the continuum, an increase in activities that fall into the disruptive category should challenge the nature of curriculum and student outcomes, and teacher and student roles. Given that currently few activities are in this category, this questioning may not be needed for a while. It is interesting however, to consider what learning for school-aged learners might look like in the future if such disruption becomes more common (Schuck, et al., 2018).

8. Conclusion

This paper has provided a rigorous analysis of those studies that have reported on mobile learning for school-aged learners. It has had a focus on innovation and disruption. While there have been other studies of mobile learning, none of the others have focused on these concepts of innovation and disruption. The results of this SLR indicate that while innovative research is occurring with mobile learning, the innovation lies on a continuum (see Fig. 3) with most studies showing either low or medium innovation. Valuable insights are derived from these results, for example indicating that disruption is not highly feasible in most practices and that support for sustaining innovations is likely to be more productive in achieving effective student learning outcomes. This recommendation aligns with Jordan's (2011) discussion of the complexity and messiness of teaching and the slow rate of change noted in adoption of educational technologies for teaching and learning. These insights are useful for policy-makers, researchers, curriculum developers and education stakeholders generally.

The SLR study provides some useful examples for teachers (see Section 5.1) to facilitate their understanding of what innovative mobile pedagogies may look like, especially feasible, innovative practices. It goes beyond anecdotal reports of innovative practice and identifies innovation in a rigorous but tangible way. Four criteria for innovation using mobile pedagogies have been identified that stem both from the innovation and the mobile learning literature (see Section 3.4). These criteria concern the nature of the task, its context, the relationship between teacher and student and student agency. These criteria are likely to be useful to practitioners as a basis for designing effective mobile activities for their students. The 57 papers analysed in this SLR needed to demonstrate effective student learning outcomes to be included in the final selection. Therefore, the study shows that innovation can occur to varying degrees across the four criteria to result in effective student learning outcomes and engagement.

The study is timely given current debates by policy makers and politicians globally about use of mobile devices in schooling. There is a focus in the media and much professional commentary on the adverse effects of school-aged students' use of mobile devices; including health, equity, cyber-safety, bullying and classroom management concerns (Corbett, 2018; Heizer, 2018). There is a perennial tendency towards moral panic (Burden, et al., 2019; Cohen, 1972) regarding any innovation, and mobile learning appears to be the latest victim. This SLR provides evidence-based guidance on use of mobile devices in schooling that provides a counterpoint to some of the existing concerns.

The understandings of innovation underlying the articles in this SLR are contributing to the project in which this study is embedded by guiding and scaffolding the design of mobile activities by teachers. The expectation is that this analysis will also contribute more broadly to the enactment of innovative teaching and learning using mobile devices.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2019.04.008.

Appendix A. List of 57 articles from final inclusion in SLR (with paper #'s from original 208 papers)

Paper #	Reference
2	Toh, Y., So, H. J., Seow, P., & Chen, W. (2017). Transformation of Participation and Learning: Three Case Studies of Young Learners Harnessing Mobile Technologies for Seamless Science Learning. *Asia-Pacific Education Researcher, 26*(5), 305–316. https://doi.org/10.1007/s40299-017-0350-5
10	Kervin, L. (2016). Powerful and playful literacy learning with digital technologies. *Australian Journal of Language and Literacy, The, 39*(1), 64–73.
12	O'Rourke, J., Main, S., & Hill, S. M. (2017). Commercially available Digital Game Technology in the Classroom: Improving Automaticity in Mental-maths in Primary-aged Students. *Australian Journal of Teacher Education, 42*(10), 4.
13	Ahn, T. Y., & Lee, S. M. (2016). User experience of a mobile speaking application with automatic speech recognition for EFL learning. *British Journal of Educational Technology, 47*(4), 778–786. https://doi.org/10.1111/bjet.12354
14	Charitonos, K., Blake, C., Scanlon, E., & Jones, A. (2012). Museum learning via social and mobile technologies: (How) can online interactions enhance the visitor experience? *British Journal of Educational Technology, 43*(5), 802–819. https://doi.org/10.1111/j.1467-8535.2012.01360.x
15	Chen, C. H., Liu, G. Z., & Hwang, G. J. (2016). Interaction between gaming and multistage guiding strategies on students' field trip mobile learning performance and motivation. *British Journal of Educational Technology, 47*(6), 1032–1050. https://doi.org/10.1111/bjet.12270
21	Hwang, G. J., Shi, Y. R., & Chu, H. C. (2011). A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology, 42*(5), 778–789. https://doi.org/10.1111/j.1467-8535.2010.01102.x
22	Leinonen, T., Keune, A., Veermans, M., & Toikkanen, T. (2016). Mobile apps for reflection in learning: A design research in K-12 education. *British Journal of Educational Technology, 47*(1), 184–202. https://doi.org/10.1111/bjet.12224
26	Shih, J. L., Chu, H. C., Hwang, G. J., & Kinshuk. (2011). An investigation of attitudes of students and teachers about participating in a context-aware ubiquitous learning activity. *British Journal of Educational Technology, 42*(3), 373–394. https://doi.org/10.1111/j.1467-8535.2009.01020.x
28	Barak, M., & Ziv, S. (2013). Wandering: A Web-based platform for the creation of location-based interactive learning objects. *Computers & Education, 62*, 159–170. https://doi.org/10.1016/j.compedu.2012.10.015
31	Hwang, G. J., Chu, H. C., Lin, Y. S., & Tsai, C. C. (2011). A knowledge acquisition approach to developing Mindtools for organizing and sharing differentiating knowledge in a ubiquitous learning environment. *Computers & Education, 57*(1), 1368–1377. https://doi.org/10.1016/j.compedu.2010.12.013
39	Wishart, J., & Triggs, P. (2010). MuseumScouts: Exploring how schools, museums and interactive technologies can work together to support learning. *Computers & Education, 54*(3), 669–678. https://doi.org/10.1016/j.compedu.2009.08.034
42	Chen, C. C., & Huang, T. C. (2012). Learning in a u-Museum: Developing a context-aware ubiquitous learning environment. *Computers and Education, 59*(3), 873–883. https://doi.org/10.1016/j.compedu.2012.04.003
44	Chu, H. C., Hwang, G. J., Tsai, C. C., & Tseng, J. C. R. (2010). A two-tier test approach to developing location-aware mobile learning systems for natural science courses. *Computers and Education, 55*(4), 1618–1627. https://doi.org/10.1016/j.compedu.2010.07.004
45	Cordero, K., Nussbaum, M., Ibaseta, V., Otaíza, M. J., Gleisner, S., González, S.,… Carland, C. (2014). Read Create Share (RCS): A new digital tool for interactive reading and writing. *Computers and Education, 82*, 486–496. https://doi.org/10.1016/j.compedu.2014.12.006
47	Ho, T. K. L., Lin, H. S., Chen, C. K., & Lee, L. (2017). The development and evaluation of a tablet painting application for enhancing the artistic expression skills of students through reflection. *Computers and Education, 115*, 56–68. https://doi.org/10.1016/j.compedu.2017.07.012
48	Hwang, G. J., Wu, P. H., & Ke, H. R. (2011). An interactive concept map approach to supporting mobile learning activities for natural science courses. *Computers and Education, 57*(4), 2272–2280. https://doi.org/10.1016/j.compedu.2011.06.011
51	Looi, C. K., Sun, D., Wu, L., Seow, P., Chia, G., Wong, L. H.,… Norris, C. (2014). Implementing mobile learning curricula in a grade level: Empirical study of learning effectiveness at scale. *Computers and Education, 77*, 101–115. https://doi.org/10.1016/j.compedu.2014.04.011
55	Schmitz, B., Klemke, R., Walhout, J., & Specht, M. (2015). Attuning a mobile simulation game for school children using a design-based research approach. *Computers and Education, 81*, 35–48. https://doi.org/10.1016/j.compedu.2014.09.001
56	Zhang, B., Looi, C. K., Seow, P., Chia, G., Wong, L. H., Chen, W., & Norris, C. (2010). Deconstructing and reconstructing: Transforming primary science learning via a mobilized curriculum. *Computers and Education, 55*(4), 1504–1523. https://doi.org/10.1016/j.compedu.2010.06.016
60	Melero, J., Hernández-Leo, D., & Manatunga, K. (2015). Group-based mobile learning: Do group size and sharing mobile devices matter? *Computers in Human Behavior, 44*, 377–385. https://doi.org/10.1016/j.chb.2014.11.078
63	Zach, S., Raviv, T., & Meckel, Y. (2016). Using information communication technologies (ICTs) for motivating female adolescents to exercise/run in their leisure time. *Computers in Human Behavior, 60*, 593–601. https://doi.org/10.1016/j.chb.2016.02.096
76	Li, S. C., Pow, J. W. C., Wong, E. M. L., & Fung, A. C. W. (2010). Empowering student learning through Tablet PCs: A case study. *Education and Information Technologies, 15*(3), 171–180. https://doi.org/10.1007/s10639-009-9103-2
78	Sanchez, E., Young, S., & Jouneau-Sion, C. (2017). Classcraft: from gamification to ludicization of classroom management. *Education and Information Technologies, 22*(2), 497–513. https://doi.org/10.1007/s10639-016-9489-6
79	Tortorella, R. A. W., & Graf, S. (2017). Considering learning styles and context-awareness for mobile adaptive learning. *Education and Information Technologies, 22*(1), 297–315. https://doi.org/10.1007/s10639-015-9445-x
82	Bower, M., Howe, C., McCredie, N., Robinson, A., & Grover, D. (2014). Augmented Reality in Education–Cases, Places and Potentials. *Educational Media International, 51*(1), 1–15.
86	Chen, C. P., Shih, J. L., & Ma, Y. C. (2014). Using Instructional Pervasive Game for School Children's Cultural Learning. *Educational Technology & Society, 17*(2), 169–182.
88	Kim, H. J., Park, J. H., Yoo, S., & Kim, H. (2016). Fostering Creativity in Tablet-Based Interactive Classrooms. *Educational Technology & Society, 19*(3), 207–220.
89	Looi, C. K., & Wong, L. H. (2014). Implementing Mobile Learning Curricula in Schools: A Programme of Research from Innovation to Scaling. *Educational Technology & Society, 17*(2), 72–84.
90	Shih, J. L., Chuang, C. W., & Hwang, G. J. (2010). An Inquiry-based Mobile Learning Approach to Enhancing Social Science Learning Effectiveness. *Educational Technology & Society, 13*(4), 50–62.
92	Wu, P. H., Hwang, G. J., & Tsai, W. H. (2013). An Expert System-based Context-Aware Ubiquitous Learning Approach for Conducting Science Learning Activities. *Educational Technology & Society, 16*(4), 217–230.
93	Huang, Y. M., Shadiev, R., Sun, A., Hwang, W. Y., & Liu, T. Y. (2017). A study of the cognitive diffusion model: facilitating students' high level cognitive processes with authentic support. *Educational Technology Research and Development, 65*(3), 505–531. https://doi.org/10.1007/s11423-016-9475-0

97 Hsu, T. Y., Kuo, F. R., Liang, H. Y., & Lee, M. F. (2016). A curriculum-based virtual and physical mobile learning model for elementary schools in museums. *Electronic Library, 34*(6), 997–1012. https://doi.org/10.1108/EL-08-2015-0146

101 Kim, P., Suh, E., & Song, D. (2015). Development of a design-based learning curriculum through design-based research for a technology-enabled science classroom. *Etr&D-Educational Technology Research and Development, 63*(4), 575–602. https://doi.org/10.1007/s11423-015-9376-7

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Appendix B. Synonyms and alternatives terms for major search terms

Mobile learning	Transformation	School-aged learners
mobile pedagog* (*mobile pedagogies, mobile pedagogy*)	disrupt* (*Disruptive technologies, Disruptive pedagogy, Disruptive approaches, Disruptive strategies, Disruptive teaching approaches*)	school* (*schooling, high school, middle school, primary school, after-school, school student/s*
mobile learn* (*mobile learning, mobile learning technology)*	transform* (*transformative*)	*school pupil/s, school learner/s*)
mobile supported learn*	innovat* (*radical innovation*	secondary education
mobile enhanced learn*	*innovative approach**	primary education
mobile supported teach*	*innovative strateg**	elementary education
mobile enhanced teach*	*innovative pedagog**	secondary-age*
mobile supported pedagog*	*incremental/radical innovation*	primary-age*
mobile enhanced pedagog*	*pedagogical innovation, innovative technologies*)	elementary-age*
mobile didactics	re-vision*	K-12
mobile teach*	reimag* or re-imag	P-12
mobile technolog* (*mobile technology enhanced learning*	renew or re-new	7–12

mobile technology-based learning	redefin* or re-defin*	K-6
		P-6
mobile technology-mediated learning	future-oriented	7–10
mobile technology-supported learning	future-focus*	K12
mobile technology integrated learning	future-proof	K6
mobile technology integration	paradigm shift	P12
mobile technology enhanced teaching	paradigm change	P6
mobile technology-based teaching	cutting-edge	youth
mobile technology-supported teaching)	contemporary	teen*
mobile digital technolog* mobile educational technolog*	progressive	adolescen*
mobile device	pioneer*	child*
mLearn* (*mlearn, mlearning, mlearner* > >)	frontier	tween
m-learn* (*m-Learn, m-learning* > >)	ground-breaking	
handheld, handhelds	groundbreaking	
Tablet, tablets	change* pedagog*	
iPad ipads	enhance* pedagog*	
android	change* teaching approach*	
app	enhance* teaching approach*	
apps	change* teaching strateg*	
app-based	enhance* teaching strateg*	
phablet	change* learning practice*	
smartphone	enhance* learning practice*	
	change* learning approach*	
	enhance* learning approach*	
	emerging pedagog*	
	new pedagog*	
	emerging practice*	
	new practice*	
	best-practice*	
	exemplary-practice*	
	emerging teaching approach	
	new teaching approach	
	emerging teaching strateg*	
	new teaching strateg*	
	emerging learning practice*	
	new learning practice*	
	emerging learning approach	
	new learning approach	

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