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On activities and affordances for mobile learning

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ABSTRACT

Across the articles in this special issue, there is a clear and important focus on how people learn through mobility, which allows them to move across contexts as they learn. This commentary considers ways mobile technologies can support learning with a focus on understanding the affordances to of the mobile technologies develop new learning practices that could not be accomplished without this technology. With this in mind, we return to the definition of mobile learning that suggests mobile learning is learning across multiple contexts, through social interaction, using personal electronic devices that can immediately capture information about, or provide information to the user. To explore how to implement this definition in truly powerful ways, we suggest explicitly unpacking this into its four component parts, so that we can explore and discuss the unique affordances of mobile learning: (1) multiple contexts, (2) social interactions, (3) content interactions, and (4), capturing information and providing information to users in real-time. We further suggest a 5th element, which is the synergies among these different dimensions. We conclude with the challenges in doing research in mobile learning environments and the need to understand both how and what people learn in such environments.

We are delighted to have been invited to comment on this special issue. It helped highlight for us the importance of considering social and cultural context and going beyond mobile learning as a black box. As the editors of this special issue note (Bernacki et al., 2020/this issue), mobile learning is defined as "learning across multiple contexts, through social and content interactions, using personal electronic devices" (Crompton, 2013, p. 4). They also note how ubiquitous mobile devices are, with over 92 percent of United States adults owning a cell phone (Schwartz, 2017). This definition of mobile learning and these statistics make obvious that the importance of mobile learning is not just about technical affordances, but also about historical context; the unprecedented access and agency that youth have today intersect with the affordances of these devices to provide truly unique opportunities for both learning and the study of learning (Ito et al., 2013).

The time is ripe for the kinds of "redefinition" that is at the extreme end of the SAMR model (Puentedura, 2009) referenced by the editors and authors in this special issue. In reviewing and reflecting on the articles presented, we believe that each empirical contribution starts to move in this direction and push boundaries, but also that future work can and should synthesize the contributions presented here as a way to truly live up to the potential that mobile learning has to offer. The authors in this special issue have given us a glimpse of this potential. We add to this consideration of ways mobile technologies can support learning the importance of understanding the affordances of the particular technologies for mobile learning to develop new learning practices that could not be accomplished without this technology.

Across the articles in this special issue, there is a clear and important focus on how people learn through mobility, which allows them to move across contexts as they learn. Several of the papers also focused on how characteristics of learners and of the contexts led to different kinds of interactions with the devices, each of which might support learning in different ways. However, we wanted to think about how to build on this platform to suggest truly unique ways of learning that leverage the affordances of the mobile technology and culture in new ways, while building on the Special Issue articles' innovations and achievements in understanding learning processes. That is, we want to build on the work of this special issue to think about how we can move beyond augmenting or modifying learning to truly redefining it (Puentedura, 2009). Sharples, Arnedillo-Sáchez, Milrad, and Vavoula (2009) argued that "A central task in the design of technology for mobile learning is to promote enriching conversations within and across contexts. This involves understanding how to design technologies, media and interactions to support a seamless flow of learning across contexts, and how to integrate mobile technologies within education to enable innovative practices" (p. 237).

With this in mind, we return to the original definition of mobile learning that was taken up in this special issue, along with the modification that Lee, Fishback, and Cain (2020/this issue) suggest: mobile

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learning is learning across multiple contexts, through social interaction, using personal electronic devices that can immediately capture information about, or provide information to the user. This definition highlights how these tools and resources and integral to mobile learning. With that focus, we see activity theory (Engeström, 1987) as powerful for helping to elaborate how this happens in and shapes social contexts, though we also recognize the importance of individual learners and cognition within that perspective (Danish & Gresalfi, 2018; Salomon, Perkins, & Globerson, 1991). Sociocultural perspectives focus on the importance of tools and resources in the ways that we experience the world and how we move tools, information, and resources across contexts to transfer participation in valued practices across contexts. From a cognitive perspective, we see ways that these tools and resources influence individual learning, also captured in Lee et al.'s (2020/this issue) definition. To explore how we can implement Lee, Fishback, and Cain's (2020/this issue) definition in truly powerful ways, we suggest explicitly unpacking the definition into its four component parts, so that we can explore and discuss the unique affordances of mobile learning: (1) multiple contexts, (2) social interactions, (3) content interactions, and (4) capturing information and providing that information to users in real-time. We further suggest a fifth element, which is an exploration of the intersections of these different dimensions.

1. Multiple contexts

Most of the authors noted that mobile learning not only allowed learners to access learning in new contexts, but also across contexts. For example, Fabian and Topping (2020/this issue) looked at how students used tablets with different software tools for learning different geometry topics both outdoors and in the classroom. We believe that this is a good start, but much more could be done to articulate how the context impacts learners. Even more importantly how movement across different contexts might provide new opportunities for and insights into learning. To help conceptualize this, we looked to activity theory as a way of describing learning activities (Danish, 2014; Engeström, 1987). As Harley et al. (2020/this issue) note, activity theory highlights how individual learners' (i.e., subjects') experiences are transformed by the mediators present in their activity context. The mediators within activity theory are the artifacts or tools that the subjects use (e.g., the specific mobile learning technologies), the object or motive that they are pursuing (e.g., trying to get a better grade or understand a new concept), the community that they are engaging with (e.g., the members of their class), and the rules (e.g., having to submit an assignment as a specific time) as well as the division of labor (e.g., students each work with different portions of the app) that help explain how the individuals within the community interact in learning. We found Harley et al.'s (2020/this issue) description of how each mediator had both a technical and semiotic dimension quite compelling, and were intrigued by the comparison that they provided across potential contexts of study in their appendix. Considering these contexts is particularly important in thinking about how they might support or inhibit learning to transfer particular practices across the contexts. To help interpret, for example, the lack of achievement differences in the Fabian and Topping's (2020/this issue) study, we would want to know more about the similarities and differences in mathematical practices in all the mLearning contexts as well as the characteristics and contexts of the experimental group.

Nonetheless, we wondered how future work might go even one step further. How could it provide even richer insights? Our pondering led us to consider explicitly how multiple contexts are present in these studies, and more importantly how movement between and across them (i.e., mobility) might influence learning? This led us to articulate a framework that explores the Mediators of Mobile Learning Across Contexts (see Table 1) as a way of conceptualizing this, with the assumption that any given mobile study must naturally consider at least two contexts or types of contexts (e.g., formal and informal) and then explicitly articulate what role the contexts are playing in learning and how they are bridged or intersect. While it is common to consider formal (i.e., in school) and informal (i.e., out of school or home) as the two most relevant contexts, we labeled ours as the first and second context to capture a broader range of possibilities, also drawing upon the authors of this issue who included different spaces within school (Fabian and Topping, 2020/this issue) or different informal spaces (Lee et al., 2020/this issue).

Once these contexts have been identified, we think it would be valuable to ask questions such as: What does it mean for a learner to move between them? And how can we design for or understand this? Returning to Fabian and Topping's (2020/this issue) work, we wonder, therefore, how moving from the classroom to the outdoor space provided new opportunities for students to consider the content they were exploring? What changed for learners? We wondered what the designers' intentions were in terms of the learning and disciplinary practices for each setting, how these were enacted, and how the designers hoped the combination of practices and contexts would add up to more than the sum of the parts. Similarly, Xie et al. (2020/this issue) examined using mobile technology to study learning, though not for learning itself, in terms of planned studying in contexts defined as home and out-of-home, along with temporal variation. We would have liked to understand more deeply what these different contexts meant to learners, and how movement between them might have helped to inform their learning experiences. For example, did the students who did not study when they had intended skip their study sessions, or simply reschedule them, giving them continued opportunities for spaced practice? Why was that, and how did it help them to have more or less productive sessions? Knowing how individual factors predicted the likelihood of studying is quite compelling, but we think future work can extend this even further by better understanding the dynamics of movement between these sites. Armed with such knowledge, how might we also design apps to encourage better study habits based on location data?

We use the example from Fabian and Topping (2020/this issue) to explain Table 1. Here, the subjects are the individuals and how their perceptions and prior experiences might affect engagement, motivation, and learning at an individual level. Across the different activities, the object was an improved understanding of relevant mathematical content and practices in geometry. Though it is worth asking whether students truly embraced this, or had a more modest and common object such as giving the teacher what they wanted. The mobile learning device was treated as the artifact for mediating the students' interaction with the content by helping them visualize and annotate the geometry in the world around them, and we suspect it could mediate the social interactions as learners shared these devices and negotiated their use.

From a sociocultural perspective, we also need to know more about how the two learning environments were set up and whether learners engaged in the kinds of active participation and discursive activity that would promote learning. The discursive activity itself is part of what socially mediates learning, whereas the technology and pedagogy would mediate both the social interaction and the content. For example, how did students negotiate what objects they would take pictures of, and how they would annotate them? Did the app shape their choices and orient them one way or the other, and did that have implications for their learning activities? Were the participation structures and norms different when moving between spaces, compared to within either space? The teacher interviews provide some information about how the activities supported learning such as visualization capabilities and the scavenger hunt. There are some hints from the student interviews as well that suggest aspects of the community that might be considered. How did power and privilege shape how the technology was used? Given the more negative perceptions of the technology among girls, we wondered what kinds of activities that the boys and girls in this context aligned with and how the learning activities were consistent with those. From a cognitive perspective, we would want to

Table 1
Mediators of mobile learning across contexts.

	First context (e.g., Formal)	Second context (e.g., Informal)	Intersection/bridging
Subject	Identity and individual differences in the first context	Identity and individual differences in the second context	How do participants move between these contexts? That is, do they start in a formal context and move to an informal context, move back and forth, etc.?
Object	Object and Goal for the first context	Object and Goal for the second context	Overarching Object
Artifacts	Engaging in the first context ● Mediating social activity ● Mediating content engagement	Engaging in the second context ● Mediating social activity ● Mediating content engagement	How does the artifact help learners move between and bridge contexts?
Rules	Rules of the firstcontext	Rules of the second context	Rules of the shared mobile space
Community	Power, privilege, and rights in the first context	Power, privilege, and rights in the second context	Combined community, privilege, power, and rights that span across the contexts, or tensions that arise from variations across contexts
Division of Labor	Organization in the first context	Organization in the second context	Organization across contexts and in-between them?
Tensions	Tensions within the first context	Tensions within the second context	Tensions that arise due to the interactions between the contexts

know more about whether the learners engaged in the kinds of constructive processing that would lead to deep learning (Chi & Wylie, 2014). Were there times when learners engaged in individual active processing while using the tablet or were particular activities more interactive, promoting deeper processing?

As far as considering contexts, there are two kinds here, the physical spaces that shape learners' ideas and expectations and the disciplinary mathematical contexts that also cue different kinds of conceptual engagement. In some of the activities, one physical space was the classroom and the other was outdoors. The particular activities and disciplinary content form another kind of context. Cutting across both kinds of contexts were tensions in the system related to working in pairs as well as tensions introduced due to technology issues. Students themselves noted that technology could be a distraction that might interfere with learning, both from other students playing with the tools but also because they needed to learn to use the technology and associated apps before engaging in activities that were geared towards the learning goals. In the sections that follow we consider some of the unique affordances, interactions, and synergies that derive from mLearning environments.

2. Social interactions

The shared definition of mobile learning highlighted the importance of social interactions that derive from mobile technologies, and we agree! For many learners, mobility and mobile devices are fundamentally intertwined with social interaction, making this a possible site for learning (Ito et al., 2013). However, what kinds of social interactions might have been present within the studies that are reported? For example, in Fabian and Topping, we can imagine that the learners might have had productive discussions around choosing what to photograph or how to annotate the photographs resulting in shared understanding (similar to the kinds of interactions reported in Roschelle (1996)). Alternatively, they might have had particular roles in terms of allocating who would have control of the tablet, guide the annotations, or ask questions that might guide mathematical reasoning about particular geometric figures (e.g., Herrenkohl, 2006). In some cases, documenting social interactions is quite challenging. For example, the study plans of the students in Xie et al.'s (2020/this issue) paper appear to be quite individualistic. However, the other papers in this issue suggest possible solutions. For example, Lee discussed how measures of arousal allowed them to look at an overly large video corpus for evidence of what kinds of interactions might have led to those moments. Might it be possible to track similar forms of social interaction around students' learning and interaction? Harley et al., reported on an initial implementation in a lab, but what about when there are participants visiting the same historical spaces? How might these mobile technologies support conversations across participants who are either co-located, or visit at different times but who can leave a digital trace? Another intriguing possibility for social interactions was found in the Demmans Epp and Phirangee (2020/this issue) article, where participants could create material for their fellow learners. How might the activity be structured to motivate the students to actually create these materials? This is particularly important in terms of learning theory, as this kind of constructive activity affords the kinds of participation in authentic practices such as creating materials for an audience that are suggested by sociocultural theories. This would also be the kind of constructive and interactive engagement that cognitive theorists argue is important for learning (Chi & Wylie, 2014).

As we note in Table 1, each location might have its own social milieu, and understanding how this differs and supports unique forms of learning might be quite compelling. How might we infer some of this from within mobile technologies? Future research might build on Fabian and Topping's (2020) work in this issue to examine processes as students move between spaces and use a mobile app to mathematically annotate the world around them. Other researchers may wish to build on Demmans Epp and Phirangee's (2020/this issue) research that examines how learners recoup down time within the margins of the school day's to pursue their own, additional learning goal (i.e. language learning via short practice activities).

How do those interactions unfold in new ways that take advantage of and build upon the movement between spaces? We wondered whether the students in Xie et al. (2020/this issue) went to study with their friends from class or others? Or whether the students in Demmans Epp and Phirangee (2020/this issue) et al. continued to interact with the app outside of class? There is reason to believe that interactions in either case might have supported learning. We were inspired here by Paquette et al. (2018) whose work demonstrated that even simple patterns in how learners navigate a shared text can predict their interactions; students who were scrolling through a worksheet were less likely to be productively interacting if they had scrolled to rather distant points. One might not normally assume that scrolling behavior was so useful for understanding group interactions and supporting instructors in intervening, but that is exactly the value of research that aims to redefine the contexts in which learners are engaging.

3. Content interactions

Naturally, some content truly lends itself to studying or understanding mobility. The papers within this special issue suggest a number of interesting cases and methods by building from different aspects of the activity system as the motive for moving between spaces. For example, Lee et al. (2020/this issue) focused on how students moved across different areas within the maker space and beyond, and looked at how this might have supported unique forms of activity. Similarly, Harley et al. (2020/this issue) provided a technology that is linked to places in the real world, so the content itself is about the location. Alternatively, Fabian and Topping (2020/this issue) had students engage in annotating their environment with geometric properties, positioning the environment at the center of their mathematical endeavors. In Demmans Epp and Phirangee (2020/this issue), learners used the mobile app to practice pronunciation at home whereas they

engaged with other aspects of the app in the school context. In all these cases, content and place are intertwined, though in somewhat different ways. In contrast, Xie et al. (2020/this issue) took a more content-agnostic approach that nonetheless allowed them to see how content learning might have been linked to a range of contexts that have differential impact on individual learners. That is, how did moving to new spaces support their study habits, or not? Research in the tradition of "learning on the move" (Bang & Marin, 2015; Leander, Phillips, & Taylor, 2010; Marin, 2013; Taylor, 2017) has explored how content and context can be uniquely linked, and how movement between spaces can support engaging in new forms of learning. For example, Taylor (2017) showed how youth learned about their city by moving through it in ways that suggest that they only truly understood the content by exploring the contexts in which it was made relevant. We believe that continuing to build on that tradition while exploring the affordances of mobile technologies for carrying learning, interaction, and knowledge between and across these spaces has the potential to open up new avenues of research and design. For example, while Demmans Epp and Phirangee (2020/this issue) appear to be trying to take the content out of the context by allowing learners to explore language across contexts, their findings suggest that the contexts nonetheless led to different use patterns, and thus may have a continued role in shaping students' learning.

4. Capturing and returning information

The last dimension focuses on how mobile devices provide the opportunity to share information with users in their current spaces in productive ways. For example, Harley et al. (2020/this issue) provided locally relevant historical information and Demmans Epp and Phirangee (2020/this issue) et al. provided access to vocabulary. As noted under content interactions, these are potentially powerful opportunities for sharing new ideas with learners when they matter. At the same time, a number of the papers also leveraged mobile technologies to collect information about learners to provide new insights into their learning processes, including when and where they were engaging in activities (Xie et al., 2020/this issue), and what their arousal state was at that moment (Lee et al., 2020/this issue). With the ongoing drive towards Learning Analytics (Rosé, 2018), we believe it is self-evident that this information can be incredibly powerful for describing and understanding learning. Here, however, we provide a cautionary note that it is also important to look into the real, lived social experiences of learners above and beyond what their data might tell us. To illustrate this, we again refer to the complexity suggested by the framework for exploring Mediators of Mobile Learning Across Contexts (Table 1); what do the contexts that are being described mean for and to learners in their own words, and how might this shed light on the measures of their activities that are being collected? How does moving between spaces change their experiences? One way to address this might be to use multiple sources of complementary data that can help shed light on what is happening in addition to where. This would be similar to how Lee et al (2020/this issue) used video data to add nuance to the claims they were able to make about what was happening when learners showed higher levels of activation. Of course, it is not always possible, or desirable, to collect this kind of information automatically. For example, in the Xie et al. study (2020/this issue), it might be the case that asking learners to reflect on why they did not always follow through on their plans might have served both as a source of data, and a metacognitive prompt to help them reflect on and potentially enhance their own study habits. Although beyond the scope of this commentary, we need to consider the privacy issues that this would raise.

5. What about the synergies across mediators?

Mobile technology provides the opportunity to consider how contexts, social interactions, and content can all interact to produce new forms of activity. The papers in the special issue provide some important first steps in this process. Fabian and Topping (2020/this issue) begin to look at this as they considered some of the social factors (e.g., working in pairs) and content. However, researchers need to better understand how the mobile technology is used in these different contexts and nature of the social interactions.

We see in the Demmans Epp and Phirangee (2020/this issue) study that the activity design for using mobile learning technology matters, however we would like to know more about the social milieu and classroom norms that would support and constrain the social interactions afforded by the app, helping us to understand any synergistic effects of the two mediators. How does moving in space provide new social interactions? In the Lee et al. study (2020/this issue) we see not only that students were more engaged during certain interactions with their peers, but we wish to explore how this was tied to different activities during different days of the maker camp. We can imagine exciting possibilities if the MALL app were used more outside of school in addition to the two in-school designs (Demmans Epp & Phirangee, 2020/this issue). If that happened, how might the app support learners in moving into that new context, and how might the interactions that occur in out-of-school contexts provide unique insights? This might provide new opportunities for exploring issues of power and privilege as learners tap into objects from their lives as a resource for exploring mathematics, rather than being limited to the kinds of in-school spaces that we know privilege certain kinds of cultural expectations.

Similarly, Harley et al.'s (2020/this issue) work will likely reveal new transformative possibilities when their app is used to support augmented reality out in the world where the historical content and local context interact. This led us to consider: how could this provide new views of content that we could leverage? How could social interactions around this content lead to new shared understanding? We also would like to see further consideration of how to use the information that is captured in mobile learning environments to support social, content, and context interactions. There are some hints of these possibilities in the Xie et al. (2020/this issue) study in terms of what information can be collected and the Demmans Epp and Phirangee (2020/this issue) study in terms of providing some level of adaptive support. Lee et al. (2020/this issue) have not yet used the information they collect to provide feedback to learners, but an author in this group has used the data that youth collect as a basis for them to engage in modeling and inquiry in other work (Lee, 2019). There could be further advantages in considering how information could be used to support teacher orchestration, social interactions, and shared regulation.

6. Beyond the black box in understanding mobile learning

Designing and studying mobile learning is hard. It is hard because, if researchers take mobility seriously, they need to consider the key tensions that arise in mobile learning activity systems. This means considering different contexts of use and movement between them, including the balance between formal and informal activities. It is also important to consider differences between intended designs and the actual enactions of mobile designs by teachers and learners in the real world (Sharples et al., 2009). We also need to consider how much of what we have seen in the research presented here is a novelty effect compared with what we would see in sustained mobile learning (Fabian and Topping's (2020/this issue) exploration of sustained use is an exception to this). To understand whether and how mobile learning is effective, we need to unpack how the mobile learning is being enacted. For example, one issue that makes mobile learning challenging to understand is the unpredictability of the learning context – how do the ergonomics, noise, social environment, and other environmental factors affect, support, constrain, and perhaps interfere with learning? This may make mobile learning particularly amenable to mixed methods and design-based research approaches to learning (McKenney & Reeves, 2018; Puntambekar, 2013).

The SAMR model provides a framework for what innovative uses of technology might look like, with redefinition as the highest level of Puentadura's (2009) framework. However, we also resonate with Hamilton, Rosenberg, and Akcaoglu's (2016) recent critique of the SAMR framework. They note the lack of a research base for the framework itself. Of equal importance, they also note the significance of considering context, pedagogy, and the rigid hierarchy presented by the framework itself. Hamilton et al. (2016) noted that "this minimizes the more important focus on using technology in ways that emphasize shifting pedagogy or classroom practices to enhance teaching and learning" (p. 437). Bringing this back to the learning theories discussed in the introduction, this recommendation requires recognizing what technology affordances are needed for particular activity systems and associated learning goals (Danish & Gresalfi, 2018; Jeong & Hmelo-Silver, 2016). For example, the Demmans Epp and Phirangee (2020/this issue) study appears to us be at the augmentation level. This level may well be appropriate for a goal of vocabulary acquisition to support spaced practice.

Thus, we suggest that if we want mobile learning to support a fundamental redefinition, researchers must consider how technology (both hardware and software) allows us to redefine and support opportunities for ambitious, student-centered learning practices (Glazewski & Hmelo-Silver, 2019). For mobile learning, this adds an extra layer of complexity as we try to consider the affordances of different environments and the capability to move around within and between them. Our goal with Table 1 was to provide a framework, grounded in activity theory, for exploring this relationship. We accomplish this by highlighting the mediators that shape learners' experiences with the technologies in disparate contexts as well as both the interactions between those contexts, the synergies across the mediators, and how they support learning.

In thinking about how a focus on mediators and synergies across mediators can support redefinition, we provide a hypothetical example. As currently conceived, the Xie et al. (2020/this issue) app supports some aspects of self-regulation through experience sampling. One could imagine how a mobile app to support studying might achieve redefinition of learning by supporting self-regulation through assisting with planning and monitoring, and also by suggesting content to study. Leveraging the device's location awareness, a notification could also be provided to people in a coffee shop who might form a study group, or a prompt might be provided to a learner that a classmate is present who they might wish to ask for help. This hypothetical app would be adaptive to person and place, and support cognitive, metacognitive, motivational, and social aspects of learning.

Building on our framework for exploring the Mediators of Mobile Learning Across Contexts, we believe that future research can benefit from explicitly designing for and studying the ways in which disparate mediators influence learning across contexts, placing the notion of mobility at the center of this effort. From a design perspective this means intentionally and explicitly designing features of mobile apps and associated activities that bridge the different contexts and mediators. For example, adding an opportunity for the learners in Fabian and Topping's app (2020/this issue) to capture and annotate objects from home and then explore them with their peers might provide deeper insights into the role and intersection between context, content, and mobility that the authors explore. Similarly, leveraging learners' locations to provide dynamic study suggestions to them as we proposed for the Xie et al. (2020/this issue) app might offer new ways of understanding how space and context can be leveraged to support more robust study habits. Along with opportunities for design, this framework also suggests that we need to continue exploring how to capture data that helps us to understand the intersection between context and mediators that occur in mobile learning. It is more important than ever to make sure that we capture participants' own lived experiences through video and interview to help make sense of the data that we capture automatically. It may be tempting to rely on easily collected information that mobile phones can provide to all users and apps, but we view that as a mistake because it hides so many of the contextual factors that help learners to make sense of their experiences.

We conclude with a plea for opening up the black box. It is essential for researchers and designers to consider the design of mobile learning environments embody the criteria that Sharples et al. (2009) and Lee et al (this issue) have identified: (1) multiple contexts, (2) social interactions, (3) content interactions, and (4), capturing information and providing information to users in real-time. Understanding the ways that the affordances are instantiated in particular designs and enacted in practice are critical for advancing our understanding of how mobile learning environments can support learning (Jeong & Hmelo-Silver, 2016).

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