Mobile Inquiry-based Learning: Relationship among levels of inquiry, learners' autonomy and environmental interaction

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ABSTRACT

This paper aims to further unpack the notion of mobile inquiry-based learning with a focus on the relationship between levels of inquiry, learners' autonomy and environmental interaction in outdoor learning. Specifically, it provides a literature review and a retrospective analysis of the empirical studies on mobile inquiry-based learning at two institutions in two countries. The goal of this paper is two-fold: i) To review the effect of the different levels of inquiry, task types and technological mediation on learners' autonomy and learners' interaction with the environment in mobile learning and ii) To revisit the notion of environment interaction in outdoor learning spaces (open and enclosed spaces). An initial retrospective analysis of our empirical studies on mobile inquiry-based learning reiterated two core findings: 1. Different levels of inquiry not only shaped learners' interaction with the physical affordances of the rich real world platform but also learners' environmental interaction in enclosed- and open-outdoor learning spaces; 2. Technological mediation plays a crucial role in enabling learners to overcome the constraints of time, space and location interaction. In this after-action-review, we identify and discuss the intricate relationship between levels of inquiry, the constituting contextual elements of the outdoor learning environment, learners' autonomy and learners' interaction with the outdoor environment. How learners leverage the physical, material and social resources in the outdoor learning context to construct and to negotiate meaning (individually or with learning peers) hinges on various dimensions of the specific learning environment: the cognitive, the geographical and the psychological space.

Keywords

Outdoor learning, learner autonomy, teacher agency, environmental interaction, inquiry-based learning, technology mediation

INTRODUCTION

The advent of new and more sophisticated mobile technologies has seen an increasing volume of research in mobile inquiry-based learning. The plethora of research on mobile inquiry-based learning can be classified into two general strands: one strand of research investigates the affordances of emerging mobile devices, Web 2.0 and Web 3.0 technologies to enhance learners' autonomy and to overcome the constraints of time, space and location (Firssova et al., 2014; Specht, Ternier, & Greller, 2011; Ternier, Klemke, Kalz, Van Ulzen, & Specht, 2012; Wong, Milrad, & Specht, 2015) and the second strand of research focuses on pervasive knowledge construction bridging in-and out-of the school learning contexts (Kerawalla et al., 2012; Tan & So, 2011; So & Tan, 2014; So, Tan, Wei, & Zhang, 2015; Tan & So, 2016; Wong & Looi, 2011). Both strands of research have made an immense contribution to the field of mobile learning. However, there remains a paucity of research on the interaction effect of task design and technological mediation on learners' interaction with the outdoor learning context. Before we adjourn further, it is perhaps helpful to revisit the notion of *mobile learning*. Sharples, Taylor and Vavoula (2005: emphasis added) reiterated that what essentially differentiates mobile learning from other types of learning is that "It is *the learner that is mobile, rather than the technology*" and they foregrounded the criticality of understanding the essence of mobile learning which is "to understand how people artfully engage with their surroundings *to create impromptu sites of learning*". In other words, Sharples and his colleagues (2005) posit that the context for mobile learning is constructed by learners' interaction with their environment and knowledge is a product of this interaction. Notwithstanding the extensive research on mobile technologies to enhance mobile learning, no empirical studies have systemically investigated learners' interaction with the outdoor learning environment in *open* space versus an *enclosed* space. An outdoor *open* space would be, for example, a river trail, a nature ramble etc., whereas an outdoor *enclosed* space would be, for example, a tunnel at a fortress, small exhibition area inside a castle. We are also interested on follow-up research efforts on the inherent challenges and implications (if any) in these two different learning spaces and how task design in mobile-based inquiry learning might mitigate the effects.

This paper provides a retrospective analysis of the empirical works on mobile inquiry-based learning carried out at two institutions in two countries: Netherlands and Singapore. The overarching research question we seek to address is: how the levels of inquiry and task structuredness shape learners' interaction with the outdoor learning environment in open and enclosed learning spaces and how technological affordances could have mediated these two learning spaces. We define technological affordances as the possibilities, the potential and the permissions that a technological artefact/ tool possesses. The succeeding sections re-examine literature review as well as empirical works (focusing mainly on research studies from two institutions in two different countries) on the effects of technology-enhanced mobile inquiry-based learning on two core variables: 1. Learners' autonomy in outdoor learning contexts and 2. Learners' interaction with the physical affordances of the outdoor learning environment.

MOBILE INQUIRY-BASED LEARNING

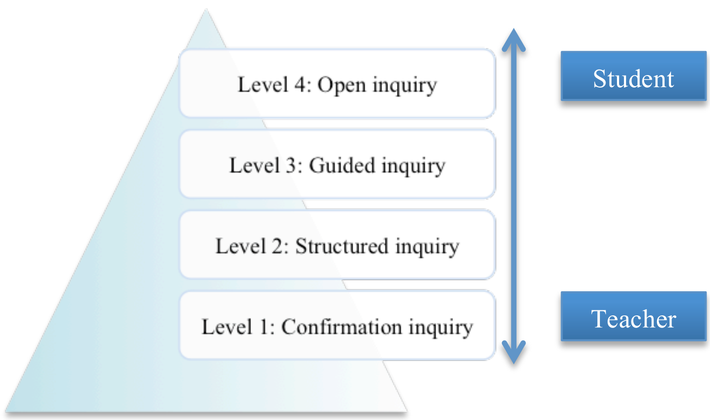
Inquiry-based learning can be traced as far back to Socrates and his preoccupations about questioning as a method to acquire knowledge. What primarily distinguishes inquiry learning from other forms of learning is that learning is *intentional* in the inquiry process: students diagnose problems, determine alternative solutions, develop investigation plans, debate with peers and develop scientific explanations (Duschl & Grandy, 2008). Constructivist theories of discovery learning form the underlying premises of inquiry learning where learners are actively engaged in constructing their own knowledge (Driver, Newton, & Osborne, 2000; Palincsar, 1998). Constructivist conceives of knowledge and learning as dependent of context, person and social situation (Jonassen, 1991).). In inquiry-based learning, learners become active agents in the knowledge acquisition process. Learners move from a passive consumer of knowledge to an active participant in constructing knowledge and/ or co-constructing knowledge with learning peers. This interdependency of the individual and collective processes also characterises the social constructivist approach (Palincsar, 1998) in collective co-construction of knowledge.The conceptual framework of promoting inquiry-based learning activities in in-and-out of the classroom also aligns with theories of situated learning (Lave & Wenger, 1991). The situated learning experiences require learners to develop a sense of situational intent (Choi & Hannafin, 1995), i.e., the capacity to leverage on relevant resources specific to that particular learning context. In a similar vein, advocates of inquiry learning contend that activities should contain an element of authenticity to enhance learning effectiveness in the (scientific) inquiry process (Barab & Hay, 2001; Chinn & Hmelo-Silver, 2002; De Jong, 2006). Authentic inquiry promotes active reflection on problems, as well as construction of explicit conceptual understanding of the problem.

This paper draws on the theories of constructivist, socio- constructivist and situated cognition to help understand and articulate the relationship between levels of inquiry, learners' autonomy and environmental interaction in outdoor open and enclosed spaces.

LEVELS OF INQUIRY: TECHNOLOGICAL AFFORDANCES AND LEARNERS' AUTONOMY

De Jong (2006) defines inquiry learning as guided discovery learning where students are provided structural support through the phases of inquiry activities from hypothesis generation to evaluating data and making scientific conclusions In so doing, learners adopt a scientific approach and make their own discoveries; they create new knowledge by activating and restructuring knowledge schemata. Akin to the notion of guided discovery learning, Tafoya, Sunal, and Knecht (1980) foreground four levels of inquiry potential: open inquiry, guided inquiry, structured inquiry and confirmation inquiry. What essentially distinguishes these four levels of inquiry is the role of the teacher and the learner on this continuum of inquiry (see figure 1). In confirmation inquiry at level 1, the teacher charters the course of the learning process, and at level 4, the students takes the lead role in managing their own the inquiry process.

Figure 1. Levels of inquiry (adapted from Tafoya et al., 1980)



We see a shift of the inquiry paradigm on the two core actors on the continuum of inquiry: a gradual increase of the learner autonomy and a fading out of the teacher as an agent in the inquiry process of problem definition, procedure planning and solutioning (see Table 2). On supporting learner autonomy, Black and Deci's work (2000) best exemplified this phenomenon where they liken learner autonomy to a situation where the learners are equipped and empowered to make autonomous decisions in the learning process given the accessibility and the availability of critical information and choice-making opportunities. On the continuum of the levels of inquiry, many scholars and researchers have both adapted these four different levels of inquiry and adopted technological mediation to promote learner autonomy in the inquiry process.

	Level 1 **Confirmation inquiry**	**Level 2** **Structured inquiry**	**Level 3** **Guided inquiry**	**Level 4:** **Open inquiry**
Problem	Teacher-led	Teacher-led	Teacher-led	Student-initiated
Procedure	Teacher-led	Teacher-led	Student-initiated	Student-initiated
Solution	Teacher-led	Student-initiated	Student-initiated	Student-initiated

Table 1. Levels of inquiry on teacher agency and learner autonomy (adapted from Tafoya et al.,1980)

For example, Firssova et al. (2014) developed the inquiry-based learning model - weSPOT (Working Environment with Personal Open Tools) to foster environmental literacy. In the weSPOT model, inquiry activities could be led by teachers or initiated by learners or by both teachers and learners. These inquiry activities ranged from highly structured to open inquiries providing maximum flexibility and freedom for learners to set inquiry goals, to define inquiry results and to organize the inquiry process. Additionally, mobile technological affordances were integrated to enable and to empower individual and collaborative inquiry work. Harnessing technological affordances was instrumental in facilitating learner autonomy in the inquiry-based learning: instructional scaffolds varying from direct prompts to indirect hints were delivered through a mobile app and a sensor-based system was used to collect energy consumption of appliances. The weSPOT model also sought to integrate scientific inquiry into the everyday situations to engender authentic learning.

In another study to support the individual or collective inquiry projects (Mikroyannidis et al., 2013), the weSPOT inquiry-based learning model was enhanced with following mobile services to support learner autonomy and self-regulation learning:

1. A mobile personal inquiry manager to support self-directed learning: learners can create and manage inquiry projects and virtual badges were awarded for acquired competences.
2. A context-aware notification system to enable contextualized sharing and notification of real world experiences: learners can link inquiry projects to specific locations, physical objects, or combinations of contextual factors, i.e. the weather at a certain location at a specific time of the year. Furthermore, notifications can trigger the collection of data dependent on several parameters (location, time, social context, environment). This enables learners to easily link objects and locations of daily life to inquiry projects.
3. A mobile data collection system to support the direct submission of sensor data and manual measurements into the workflow system, to collect data to test a hypothesis. It also supports submission of annotations and multimedia.

Findings from the questionnaires in the weSPOT project showed that students could be overwhelmed if the cognitive requirements demanded by the system were too high. Also, motivation diminished and the learning effect was not as expected owing to a lack of structure and teacher support. To advance the research on mobile inquiry-based learning, some members of the weSPOT team went on to develop the DojoIBL web-based platform (Suárez, Ternier, Prinsen, & Specht, 2016) where the inquiry process was segmented into phases, and the phases into activities, in order to provide implicit guidance during learners' inquiry process. Using roles was an important part of this design approach and the goal was to structure the learning process. One of the aims of DojoIBL was also to reduce extraneous cognitive load, by ensuring that all elements included in DojoIBL add value to the learning. The DojoIBL platform enables the teacher to structure the inquiry-based learning process by means of activities. DojoIBL works in formal contexts (e.g., the classroom, the school environment) as well as in informal contexts (their smartphones, laptops or tablets on the move). The Mobile Messaging component and the Mobile Notification component in DojoIBL also enabled quick communication channels among students and teachers thereby increases awareness of the learning progress at both the individual and collaborative level.

The second strand of research gave focus to pervasive knowledge building bridging in-and-out of the classroom learning contexts. Within the framework of guided and structured inquiry, task design with varying degree of structuredness was explored to increase learner autonomy in mobile inquiry-based learning. Task type and structuredness ranged from well-structured tasks to ill-structured task on a mobile learning trail (Tan & So, 2011; 2015; 2016). The mobile learning trail tasks range from performative to knowledge generative task type. Well-structured tasks are performative tasks (e.g., locate the direction of the guns at the fortress using the iPad compass): the task complete process is rather prescriptive and procedural, leaving little room for negotiation, judgment and conflict among group members. On the other hand, ill-structured tasks are knowledge generative tasks (e.g., locate tunnel B and explain the purpose of the tunnel): the course of learning focuses on generating, communicating and co-constructing ideas. In a performative task type, students are expected to apply knowledge and skills learned in pre-trail lessons in school to real-world contexts. Whereas, knowledge generative tasks often multiple answers and/ or solutions where students need to propose evidenced-based explanations in consideration of the multiple dimensions in that specific context.

For the series of studies on task design and learners' autonomy (Tan & So, 2011; 2015; 2016; Tan, So & Zhang, 2012), leveraging the affordances of mobile device and Web 2.0 technology was also pivotal to foster learners' autonomy in mobile inquiry-based learning contexts. Technological mediation and online platform afforded the immediacy of feedback and interaction with teachers and learning peers as learners moved from one activity station to another during the mobile learning trail. The 'alert' function cum instant feedback from teachers enabled a review of work processes. The immediacy of feedback from teachers and peers also enhanced students' autonomy and thereby increased students' capacity to take control of their own learning journey in a mobile learning environment. Students were given more autonomy to re-evaluate their initial findings and re-negotiate meaning. Another interesting observation by one of the teachers was that students were less inclined to request for answers from the teachers during virtual facilitation, however, students were very likely to ask for clues if they met the teachers (physically) during the learning trails. Teachers felt that virtual facilitation has enabled a different form of teacher involvement and the implementation of guided inquiry and/ or structured inquiry affords more reflective learning in the inquiry process as compared to a physical classroom context and/ or constant physical presence of the teachers during outdoor learning. Overall, teachers were positive that students obtained a greater sense of ownership of their learning processes in the learning trail.

ENVIRONMENTAL INTERACTION IN OUTDOOR LEARNING ENVIRONMENT

Learning in the authentic outdoor environment enables students to leverage on the physical affordances of the real-world platform in the meaning-making process. The on-site outdoor activities seek to maximize the presence of a real world platform, engaging students in meaningful knowledge creation and construction where "the process of learning is informed by sense of place" (Lim & Barton, 2006, p.107). This sense of place in situated learning experiences refers not only to the geographical locations, but also to the cognitive and psychologically affected space in outdoor learning environments. Frohberg, Göth, and Schwabe (2009) accentuate the importance of positioning mobile learning as socio-cultural activities and the criticality of designing learning activities that foster both physical interaction with multiple resources available in physical environments as well as social interaction supported through the mediation of mobile technologies (Kerawalla et al., 2012; Pachler, Bachmair, & Cook, 2010).

In mobile inquiry-based learning, students assume an active role in constructing knowledge during the interaction with the physical environment where the "direct experience with concrete phenomena and materials " (Orion, 1993, p.325) becomes key in the meaning-making process. Orion, Hofstein, Tamir, and Giddings's (1997) study found that active interaction with the environment is instrumental in the meaning-making process on an outdoor field trip. Kerawalla et al.'s (2012) research on learners' interpretation of and interaction with the environment on a geography field trip showed that apart from the use of mobile technologies, learners had to leverage multi-modal semiotic resources such as gesture, gaze, and bodily location in the meaning-making process. Akin to Pachler's (2009) notion of mobile learning, learning is conceived "as semiotic work and meaning making in which users develop, with the aid of devices, new cultural practices with and through which they learn and strengthen their resources for meaning-making whilst interacting with the world ... (p.5)". Learners become active agents in the meaning-making process in an outdoor learning setting where they undertake activities to interact with the environment to concretize or create knowledge which culminates in the development of "new cultural practices", and thereby, strengthen their "resources for meaning-making".

LEVELS OF INQUIRY: OUTDOOR-OUTDOOR VS. OUTDOOR-INDOOR ENVIRONMENTAL INTERACTION

Orion and Hoffstein's (1994) works on the notion of *novelty* space in outdoor learning foreground three essential pre-field variables, namely, the cognitive, the geographical and the psychological novelty. Cognitive novelty refers to the concepts and skills learners would be confronted with during the field trip; geographical novelty is related to learners' familiarity with the location of the field trip; and psychological novelty refers to the psychological readiness, and inherently, learners' prior experiences with outdoor learning experiences. They observed that students showed better learning performance on a field trip when this novelty space is reduced. This could possibly imply that the body of knowledge resources made available and accessible for learners via task design and technological appropriation could significantly reduce all three novelty spaces and enhance learners' interaction with the outdoor environment.

While we have no lack of research on context-crossing, i.e., indoor to outdoor, in the classroom and out-of-the classroom; formal to informal learning contexts, there is almost no research till now that carry out a systemic study on context-crossing from outdoor open space to the outdoor enclosed space which we coined as *outdoor-outdoor* learning space and *outdoor-indoor* learning space respectively. As aforementioned, an example of an outdoor-outdoor learning space would be a river trail or learning trail at a fortress. On the other hand, an outdoor-indoor learning space would be a museum exhibit at a fortress, art gallery, science centre, supermarket etc. Specifically, we are interested to explore how task design within the levels of inquiry could shape learners' environmental interaction in these two different outdoor learning contexts, i.e., if students feel restricted and restrained in an enclosed space and how less structured tasks might enhance environmental interaction. Conversely, in outdoor-outdoor learning space, task design might require more structuredness to guide students' inquiry process owing to the richness of the physical affordances in an open space.

In one of the research studies on a mobile learning trail at an island, an interesting finding is the effect of the presence of the unforeseen variables in the real world environment on task structuredness and environmental interaction (Tan & So, 2011). Analysis of all three groups' collaborative discourse for performative task type (i.e., well-structured task) showed that skill-based and straight-forward application tasks could generate some in-depth clarification, interpretation and evaluation statements in the epistemic dimension. We attribute this phenomenon to the rich affordances of outdoor learning contexts, where students were confronted with the real world platform to translate their acquired geography skills and knowledge into practice. Notwithstanding the mundane procedural tasks were often easily accomplished in the four walls of a classroom, the presence of the real physical environment certainly presented a different facet. The seemingly straight-forward application tasks such as the measuring and ranking of the gradient of slopes at the designated beach sections during the island trail, and calculating tower height at the observation point saw unusual engagement in the task-discourse and greater collective knowledge construction. For example, students found the application of known formulas was no longer as clear-cut owing to the spatial scale of the island as compared to the school's field where they practiced measuring the gradient of the slopes. The problem-solving process necessitated re-negotiation and reaffirmation of collective ideas and consensus. Students had to exercise more critical thinking in the course of finding and affirming solutions collaboratively (Tan & So, 2011).

In two studies, Tan and So (2015; 2016) investigated the use of BIG (Beyond Information Given) approach and task structuredness to enhance environmental interaction where learners undertook different task types in both outdoor-outdoor learning space (e.g., open learning space along the trail on an island) and outdoor-indoor learning space (enclosed learning space e.g., tunnels with exhibits and displays on an island). Analysis of group A's discourse showed learners in an enclosed learning space approach exhibits and displays to look for answers to the inquiry tasks regardless of the task type and task structuredness (Tan & So, 2015). For instance, learners were asked about the dimensions of a tunnel and its purpose; a performative task and a knowledge-generative task type respectively. In a bid to save time and human resources, group eventually spilt up to look for answers in the exhibits and displays. Learners were unable to allow the environment to speak to them amid the rich affordances of the physical environment in mobile learning. Neither were they able to comprehend the requirements of the task question correctly. The engagement and interaction with the artifactual resources (exhibits and displays) became brief, superficial and conservative. Artifactual resources in the tunnel became a restraint rather than a resource. For example, learners were tasked to describe the dimension of the tunnel, they were unanimously certain that the dimension of the tunnel resided in the artifactual resources such as exhibits and displays delivering information about the history and structure of the tunnels. Learners approached exhibits and displays chiefly to look for answers (Tan & So, 2015). However, analysis of group B's discourse showed some differences in their interaction with the learning environment in an enclosed space. Similar to group A, they began looking for answers in the exhibits and displays for dimensions of the tunnel and purpose but they eventually moved away from the exhibits, and came together to discuss, make reference to spatial resource in their description of the tunnel. Learners in group B were not entirely constrained by the provision of artifactual resources on field trips; rather, they were able to interact with the current environment and ride on the affordances of the semiotic resources resided in the specific situation to re-negotiate shared meanings. Akin to what Lim and Barton (2005) advocate that, 'the process of learning is informed by the sense of place', Group 2 developed a sense of situational intent and was able to engage with the both the artifactual resource and spatial resource to make valid interpretation and inferences.

As exemplified above, task design alone may not suffice to empower students to interact with the environment in a meaningful way. Technology mediation is equally instrumental in enhancing learners' interaction with the outdoor environment. Tan and So (2011) leverage technological affordances to enrich learners' environmental interaction: artifacts, channels, or users are enriched with aggregated sensor information. Enrichment is premised on a specified mapping to link an attribute of an entity to a raw data stream. Through such mapping, devices and users became aware of which sensor data is relevant for them and what information should be delivered to them. As a consequence of the enrichment process, each artifact, user, and channel were enriched with context metadata. It enabled learners to gain a deeper understanding, experience embedded learning content in real world overlays, or explore content driven by their current situation or environmental context. Most prominent examples support exploration of the physical environment with different topics of interest, e.g. history, arts, technology, biology, astronomy, and others, or by enriching artifacts in the physical environment with AR techniques (Specht et al., 2011). Software applications open new possibilities: afford reusuable structures, embedded multimedia, storage and retrieval. In another study, Ternier et al. (2012) investigated the architecture of the ARLearn system to provide highly flexible support for different educational settings: one of which was a Florence field trip case where an excursion script was created to support a city tour. This was implemented with a monitoring tool for the educator and using mobile devices with the ARLearn client installed in the physical environment with the learners (Ternier et al., 2012). The teachers found that the students were able to reflect in contexts and create learning content and successfully construct new knowledge as they moved from one location to another. Though the students were apprehensive about being monitored virtually by the teachers, they appreciated the technological affordances which enhanced their interaction with the environment.

CHALLENGES AND IMPLICATIONS

This initial retrospective analysis of the empirical works in two institutions on mobile inquiry-based learning surfaced some inherent challenges in mobile learning, in particular, in outdoor learning environment. The empirical findings also showed that the potential of web 3.0 technologies, coupled with informed instructional design when appropriately adopted, would be able to foster autonomous learning and enhance learners' environmental interaction. What is germane to increasing learner autonomy and enhancing learners' interaction with learning environment? We will highlight three core challenges and implications from our series of research studies in response to this overarching reflection question.

1. Teacher agency versus learner autonomy: The measure of teachers' presence and participation (physical and/or virtual) ought to be weighed in the context of the learning situation, the prevailing socio-cultural practices and the profile of the learners. The empirical studies in both institutions surfaced this salient point that learner autonomy to exercise more self-regulation in the learning process rests neither on technology mediation nor task design nor a combination of both, but a holistic approach with sound understanding of the learning content and context. For students to be able to benefit from autonomous learning in a mobile inquiry-based learning context, autonomy support begins with the day-to-day instructional program. Students' confidence and comfort level to initiate and pursue inquiries, to make informed decisions, and to conduct constructive interaction discourse is a gradual developmental process, orchestrated by the teacher. In Uden's (2007) paper on activity theory for design mobile learning, he reiterated Ellis' (1993) observation that, "The teacher thus has the role of a group member that has the option to qualify the dialogue through questions" (p. 22). The teacher's presence as a participant and a collaborator serves as a form of facilitating and regulating the exercise of autonomous learning. Further, student autonomy also rests largely on the presence of the collective body of their fellow workmates and the collaborative learning space. Hence, supporting learner autonomy is not a simple equation of decentralizing teacher agency and control; rather, it calls for an informed action taking into account all contextual elements in the said learn setting.
2. Technological affordances: Mobile devices and Web 3.0 are mediating tools that not only afford learners immediate interaction with the rich physical affordances of the outdoor environment, but also facilitate the immediacy of feedback, interaction and collaboration with both learning peers and teacher(s). On the other side of the coin, technological affordances has also opened the pandora box of unprecedented possibilities. Westera's (2011) work reiterates the significance of technology as one of the key drivers for contextualised learning, but also cautions against a complacency that technological mediation per se can materialise unguided autonomous learning. Harnessing technological affordances has redefined the notion of content creation and knowledge construction. New information and communication technologies like mobile devices, geopositioning services, ambient environments, and ubiquitous access have richly enlarged learners physical range of operations as well as choice-making opportunities by enabling augmented reality layers to be superimposed on existing contexts. The context of learning has become more dynamic and more responsive but also greatly intangible and incontrollable. Notwithstanding technology-mediated cognitive tools can engage learners, enhance learning effectiveness, empower and enable synchronous and asynchronous interaction and collaboration, some measure of guided inquiry is still necessary. Teachers presumably best function as facilitators to scaffold the learning milestones from confirmation to open inquiry.
3. Task design: the appropriation of the four levels of inquiry and task type ought to align with the desired learning outcomes, the outdoor learning contexts (open vs. enclosed spaces) and students' capacity for autonomous learning in situated learning. The theoretical premises of situated cognition accentuate the dynamic interplay of critical constructs such as the learning activities, all mediating tools (e.g., physical environment, social actors, artefacts, etc.), and importantly, the cultural and social practices in the learning context. According to Brown, Collins and Duguid (1989) "Knowledge is situated, being in part a product of activity, context, and culture in which it is developed and used" (p.32). Second, the theoretical underpinnings of situated cognition provide a conceptual framework to make sense of student autonomy and teacher agency in a mobile learning trajectory for it is impossible to discuss sensibly the changing roles of teachers and students without making reference to the contextual configurations and their relations. Brown and Duguid (1993) contend that, "One of the powerful implications of situated learning is that the best way to support learning is from the demand side rather than the supply side…" (p.8). Hence, task design should enable learners develop a sense of situational intent. Of significant signpost is the orchestration of guided inquiry as a preamble for learners to move to the level of open inquiry where learners generate their own inquiry questions in outdoor learning environment. Another important finding from our research was how levels of inquiry and task design shaped learners' inquiry process and environmental interaction differently in outdoor-outdoor learning space and outdoor-indoor learning space. As we have presented in this paper, performative tasks do play important roles in supporting learners to internalize and externalize their knowledge and skills. Specifically in the context of outdoor learning, applying knowledge and skills learned in classroom is not straightforward in authentic contexts due to unforeseen variables and complex interaction with the physical environment. Such complex situations of application are important learning opportunities for students to learn disciplinary problems through struggles, conflicts and even initial failures.

CONCLUSIONS

This paper reports our initial efforts in a retrospective analysis to explore the relationship between levels of mobile inquiry-based learning, technology mediation, learners' autonomy and learners' environmental interaction. It also aims to reconceptualise outdoor learning by distinguishing between outdoor-outdoor and outdoor-indoor learning space and to accentuate the criticality of orchestrating mobile inquiry-based learning tasks and harnessing technological affordances to facilitate learners' interaction with the environment and with their learning peers in these two *different* outdoor learning spaces.

The empirical studies in both strands of research foreground MIBL as an effective instructional approach which engenders learning in the real world context and enhances learners' interaction with the outdoor learning environment. Whilst the different levels of inquiry indicate the gradual increase or decrease of teacher agency and student autonomy, lesson objectives and task design would still need to take into consideration the (changing) contextual elements in mobile learning contexts, in particular, in outdoor learning environment where semiotic resources as actions, materials and artifacts (in the physiological, as well as the technological realm) do not remain static. This is made dynamic and/ or more complex when we consider that learners have to leverage multi-modal semiotic resources such as gesture, gaze, and bodily location in the meaning-making process. Likewise, task design within the framework of inquiry levels for mobile learning should not undermine the effects of open and enclosed learning spaces in an outdoor environment on learners' sense-making process and their capacity to develop a sense of situation intent. Further, in our context of mobile inquiry-based learning, the imminent challenge would be to apportion the right measure of teacher presence (virtual or physical) without jeopardizing student's capacity at autonomous learning. On the same token, one must not over-rate the power of technological mediation to increase learner autonomy and enhance environmental interaction in such a dynamic and mobile learning context

We acknowledge that there could be inherent limitations in our findings and conclusions as mobile inquiry-based learning design and practices vary from context to context and across different subject disciplines. Further, the communities of practice and the socio-cultural conditions of learning can neither be predetermined nor prescribed. Nevertheless, our first efforts at a retrospective analysis provide some initial insights into the richness of an outdoor learning context, in particular, the opportunities and challenges in exploring the material conditions for learning to understand how learners leverage use of multiple semiotic resources to create content and to (co-) construct knowledge. We believe that this study reiterates how the three intricate dimensions – task design, discursive practices, and facilitation – are unfolded in the situated context of mobile inquiry-based learning. We argue that a balanced approach in task design and technological mediation is critical to bring about the desire outcomes of outdoor learning. To conclude, the artful balance of teacher agency and student autonomy requires a sound understanding of the content and context of learning, and the appropriation of relevant technological mediated tools and facilitation.

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