Rethinking the Impact of Activity Design on a Mobile Learning Trail: The Missing Dimension of the Physical Affordances

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Abstract—This paper investigates the relationship between activity design and discourse on a mobile learning trail, considering the physical affordances of the real world platform in designing contextual learning experiences. We adopted a *context-oriented* and *process-oriented* pedagogical approach in designing the mobile learning trail conducted at Singapore Sentosa Island. Activities were categorized into *performative* and *knowledge-generative* on a continuum from well-structured to ill-structured activities. To examine the impact of activity design on discourse types, all audio-recorded verbal data of the three groups of secondary students was analysed with respect to two key dimensions in the knowledge construction process, namely, *the epistemic* and *the social*. Analysis showed that activity types and physical affordances of the learning environment have a definitive bearing on group discursive moves. Importantly, the presence of a real world context could generate critical thinking and collaborative knowledge building even for mundane performative activities when they are embedded with unforeseen contextual variables. We argue that the design of activity and the degree of its structuredness, and the assumed desired learning outcomes, are very much subjected to the affordances of physical and social resources in the mobile learning environment—a missing dimension that could possibly be overlooked and understudied.

Index Terms—Collaborative learning, mobile learning, discourse, physical affordance, activity design

1 INTRODUCTION

The advent of mobile devices and emerging technological tools and applications have dramatically revolutionised the teaching and learning landscape; creating new and exciting possibilities for learning beyond the four walls of the classroom, and thereby, inevitably changing the role of both the learner and the teacher. Seamless learning across contexts and spaces is now made possible with the affordances of mobile computing and web applications.

While there is extensive research and literature on leveraging emerging mobile devices and web technologies to enhance the learning experience in the real-world setting and learning on the move [1], [2], [3], there remains little empirical research on other equally significant configurations of mobile learning: that is the *design configuration* of mobile learning environments and the execution path to bring about the desired learning outcomes. Another common pitfall is the focus on the unending possibilities of mobile devices and innovative software applications over the rich affordances of the physical environment in the context of enhancing mobile learning.

Related to the theme of the special issue, this research examines the design configurations and the affordances of real-world contexts for promoting contextual mobile learning experiences. In particular, we advocate that mobile learning design should go beyond technological applications to embrace a wide ecology of resources in the physical and social worlds. We concur with Salomon [4] that "the whole learning environment, not just the computer program or tool, be designed as a well orchestrated whole" (p. 64) in designing effective learning environments. Here, the "orchestrated whole" ought to be seen as a cohesive body that encompasses curriculum design, desired learning outcomes, teacher-student and student-student collaborative learning space, cohort of students and socio-cultural learning conditions of that said learning environment.

As such, our theoretical framework and research methodology in designing mobile learning gives emphasis to both context-oriented and process-oriented learning trajectory. By *context-oriented*, we refer to both the physical and social context where discourse is embedded and understood. Further, we deem it more relevant to locate mobile learning not in the affordances of technology per se, but rather, in the dynamics of the real world context. Hence, we foreground the learner(s) as an important social actor(s) in this intricate and complex learning scenario. For a *process-oriented* methodology in design and implementation of mobile learning [5], we give emphasis to the design of activity-types that aligns with the desired learning outcomes. The apportioning of facilitation and the appropriation of technological mediation also forms an integral part of the process-oriented design of the entire mobile learning situation.

The structure of this paper is as follows. First, we present our theoretical framework focusing on the need to rethink about the meaning of context in mobile learning, and the criticality of the process-oriented approach in mobile learning

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design configurations. Second, we present a three-prong approach (F.A.T)—Facilitation, Activity in-situ, and Technology—as a useful framework for designing contextual mobile learning. Among the three components in the FAT framework, this paper particularly focuses on the impact of activity-design and the physical affordances on mobile learning in situ, namely: a) To what extent activity-design and activity-structuredness impact discourse moves in a mobile learning context; and b) how the interaction with the physical affordances of the outdoor learning context impact activity structuredness and discourse. Lastly, we present the analysis of discourse data from three groups of students who participated in a mobile learning trail, and discuss the implications of our research findings on the design configurations in contextual mobile learning.

2 Theoretical Framework

2.1 Rethinking Context in Mobile Learning

Before proceeding to affix a sound theoretical framework for the mobile learning environment, it is necessary to revisit the nuances of the seemingly related terms in the field of mobile learning, namely, *learning In situ*, *location-based learning*, and *situated learning* since an understanding of the context of mobile learning is imperative in designing and aligning the learning situation with the desired learning outcomes. The literal translation of the Latin expression "In situ" is "In position". This is somewhat similar to Benford, et al.'s [1] exposition on location-based learning where they contend that in location-based learning, "players must be in the same spatial locale in order to share information and act together" (p. 721). The emphasis here is on the locale and more importantly, collective cognition occurs when the body of individuals have access to the same location.

However, *learning in situ*, according to Lave and Wenger [6] could not fully articulate the central idea of situatedness, which characterises the nature of learning. They see learning as a situated activity and conceived of the "agent, activity, and world as mutually constitutive" (p. 29). Here, learning is reciprocal, reflexive and communal. Such a stance on situated learning somewhat mirrors Pachler's [7] notion of mobile learning where he reiterates that the focus ought to be on "contexts, context generation and context crossing" and defines learning in a mobile context as "semiotic work and meaning making in which users develop, with the aid of mobile devices, new cultural practices with and through which they learn and strengthen their resources in meaning making whilst interacting with the world" (p. 5).

In a mobile learning context, it is helpful to visit Goodwin's [8] postulation of changing contextual configurations. Goodwin contends that contextual configuration does not and cannot remain constant for "as action unfolds, new semiotic fields can be added, while others are treated as no longer relevant" (p. 21). This implies that the actions and thought processes experience a course of continual change as new semiotic resources enter and exit the context. Thus to this end, participation framework, interaction patterns and the building of action are subjected to the fluidity of contextual configuration specific to the moment and to that particular context. As such, participants alter their course of actions accordingly, to accommodate, to adapt to new configurations, and to realign with the emerging artifactual, spatial and social resources in the physical environment. Simiarly, Kukulska-Hulme and Sharples [9] highlight the fluid and unpredictive nature of context in mobile learning, saying "context becomes a continually unfolding property of the interactions between people and their goals, settings, and technologies. Context cannot be easily predicted in advance, but is shaped from minute to minute by mobile learners and their devices" (p. 159).

In theorising mobile learning, Sharples et al. [10] 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 contended that a fundamental concern in understanding the essence of mobile learning is "to understand how people artfully engage with their surroundings to create impromptu sites of learning". Hence, we are inclined to adopt "situated learning" as our frame of reference for our research focus on activity design and discourse on a mobile learning trail.

One approach to support situated learning experiences in school is through the form of field trips (e.g., excursion, outdoor learning, etc.). Previous research on field trips reveals that the educational effectiveness of a field trip is controlled by its structure, learning materials and the interaction with the environment [11]. Field trip visits often result in the students experiencing many phenomena and ideas that are new to them, where the individual is situated, and ultimately have a strong influence on the ways in which knowledge is constructed [12]. In the field trip, the environments cannot be pre-specified. Therefore learning in the field trip including re-conceptualisation is created through the activity of learning where knowledge is dynamically constructed by learners interacting with their surroundings [13]. Here, learners not only construct meaning on their own, but also with others to apply knowledge in real world context [14]. Collaborative learning in the field trip is thus, conceived of as active participation and interaction both with the environment and with others to negotiate meaning [15].

Research studies on mobile learning also investigated the use of mobile technologies and applications supporting learning in a real-world setting. Smith et al. [16] compare the outcomes of the two similar mobile learning design supporting collaborative scientific field inquiry where students aged 14-16 years old used mobile devices (PDA) with data-logging technologies to explore the understanding of CO air pollution in a real-world context. They found that while the two projects used similar technologies and learning activities, the learning process and interaction patterns were rather different due to types of facilitator input and in-situ data collection methods. This study highlights the importance of scaffolding by both technological tools and human facilitation for creating effective in-situ scientific inquiry experiences.

In another study, Squire and Klopfer [3] present the design and enactment of the handheld augmented reality (AR) simulations that allow students to engage in both virtual and real contexts of science investigations. They found that the augmented reality simulations provided an opportunity for collaborative narratives that students were engaged in simulating themselves into the practices of real science investigation and had situated experiences about the complexity behind the inquiry process in real contexts.

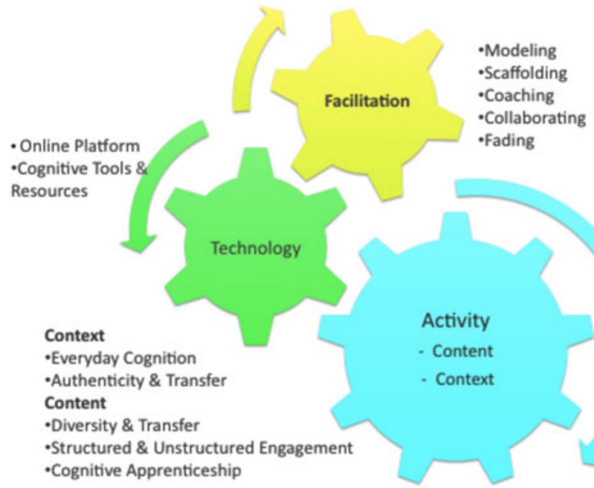

Fig. 1. F.A.T. Framework.

Similarly, Kamarainen et al. [17] investigated the use of AR in mobile learning in field trip contexts. They integrated AR and probeware to mediate collaborative scientific inquiry in the field trip where sixth graders participated as part of their environment education. This study found that such a learning environment led to gains in students' content understanding as well as positive affective measures. The students were able to demonstrate deeper understanding of the principles of water quality measurement after participating in the authentic field activities supported by mobile devices and scientific inquiry tools. In sum, the prior research has demonstrated that well-designed mobile learning in real-world contexts can provide a useful platform for leaners to apply and contextualize what they learn in classroom.

2.2 From *Context* to *Process*: A Shift of Focus

Having laid the context of mobile learning and positioned *context* as pivotal in design considerations for a mobile learning trail, it inherently implies a need to examine the *process* of learning taking place in this *context*. The contention behind situated learning aligns well with our research focus on *process* where we see *discourse* as primary, and *technological tools and facilitation* as assuming a critical supporting role. Strijbos et al. [5] conceptualize the idea of a process-oriented methodology and reiterate that interaction forms the central locus in designing any (computer-supported) group-based learning (CSGBL). All components that could impact, influence or shape that preferred and/ or desired interaction ought to be considered in a process-oriented research methodology. This is similar to what Dillenbourg [18] advocates on "designing the situation" to see the occurrences of the desired interaction patterns and discourse types.

In staging the learning situation to see the desired learning outcomes and discourse types in contextual mobile learning, we are inclined to concur with Strijbos et al.'s [5] process-oriented methodology. Here, we present a three-prong approach (F.A.T)—Facilitation, Activity in-situ, and Technology as a useful process-oriented framework for designing meaningful contextual experiences in mobile learning environments. Our conceptual framework, F.A.T (Fig. 1) gives emphasis to the design of activities that leverages on the 'sense of place' and its affordances to bring about the desired discourse. Below we articulate the critical role of *activity type*, *technological mediation*, and *facilitation* as the key determinants framing learners' discourse and interaction patterns in contextual mobile learning.

2.2.1 Activity-Type

We shall begin with activity-type as the primary driver in framing interaction discourse and patterns in mobile learning. Activity design and activity structure play a definitive role in determining discourse types and discourse moves [5], [19], [20], [21], [22], [23]. The notion of activity-type is best understood in Strijbos et al.'s [5] exposition on the works of McGrath and Hollingshead [24] where they surface two continua hosting the variety of task-types: with "cognitive to behavioural tasks" on one continuum and "cooperative tasks to conflict-oriented" task type on the other continuum. In sum, the generation of statement types rests very much on the activity type. For instance, conflict-oriented activity-type is likely to yield more occurrences of agreeing, disagreeing, negotiation and evaluation statements whereas cooperative activities will see more instances of approval, clarification and confirmation statements. On a similar note, Weinberger and Fischer [23] posit that different epistemic activities will breed different discourse types for "learners construct arguments in interaction" and that "learners engage in specific discourse activities" (pp. 72-73) to acquire knowledge. Here, it also speaks of intentional design of activities to bring about the preferred discourse types and/ or a combination of discourse types to enable learners to acquire a variety of skills, concepts and knowledge.

Taking a step further, at the micro level of activity-type, an investigation into activity-structuredness will afford us more insight into the intricate relationship between activity-type and discourse type. On a continuum from well-structured to ill-structured activity-types, it is postulated that well-structured activities are likely to bring about lesser interaction, lower critical thinking discourse types whereas ill-structured activities allow greater diversity of ideas, negotiation and convergence of shared understanding [5], [21], [25].

2.2.2 Technological Mediation

By technological mediation in our research context, we refer to both the use of mobile devices, as well as, the affordances of web-based platform, to provide cognitive support and scaffold on a mobile learning context. Mobile devices and technological applications are mediating tools that allow people to capitalise on the situation in terms of the immediate physical space, while encouraging social communication and archiving in ways that could enhance the learning context. Technology-mediated tools are significant instruments whereby constructivist learning activities are carried out, empowering the learners to manipulate and create knowledge [15]. For instance, Bereiter and Scardamalia [26] argue for the critical role of technological mediation that a technological tool such as Knowledge Forum can provide both social and cognitive supports for students to advance ideas collectively, creating a continuity of knowledge building discourse. In situated learning environments, similarly, the accessibility and the provision of assorted cognitive tools and resources seek to support student-centered learning, and these tools range from manual devices to digital resource support such as resource files, databases, simulations, and communication tools [27].

Further, Pea [28] and Salomon et al. [29] posit that cognitive tools possess the capacity to amplify and augment mental functioning. Likewise, the field of cultural geography, sociology, and anthropology reiterates the mediating role of technologies in influencing and structuring the interaction between the individual and his or her social real-time milieu [30], [31]. However, Strijbos et al. [5] caution against expecting total compliance from learners on the intended use of a given device and technological support, and advocate the necessity of allowing room for "desired cognitive residue" [4] where variables in the learning context could possibly impact the way learners leverage on prescriptive technological tools. It is important to note that technology is designed to facilitate, rather than, to prescribe mobile learning experiences.

2.2.3 Facilitation

Essentially, *questioning* forms a significant milestone in facilitation discourse. Cho et al. [22] spoke of "question prompts" as a measure of providing students with cognitive support in their own undertaking of participants' questioning discourse. Further, citing the works of Graesser et al. [32], Cho et al. [22] expounded on the types of question and highlighted instrumental, procedural, enablement and expectation questions, as question-types that are likely to bring about deep-reasoning and deep-thinking amongst the learners. Likewise, Hmelo-Silver and Barrows [33] accentuated the need for teachers to leverage different discourse strategies "to promote constructive processing"—use of questioning techniques to enable and empower students to progress to higher-level critical thinking.

To empower students to become agents of their own learning in a mobile learning trail, good questioning techniques can assist students to assume this responsibility. Questioning seems to serve as a must-have measure in structuring and scaffolding students' learning processes. Scardamalia and Bereiter [34] surface the notion of "procedural facilitation" and caution against constricting learners' capacity to negotiate contextual variables in the meaning-making process. Instead, they advocate the need to diagnose and to assess the situation before apportioning the measure and mode of facilitation.

2.3 Purpose and Significance of the Study

Learning outside the classroom is not straightforward due to the complexity of the real world environment. Following the core idea of the FAT framework, this study highlights the importance of factoring in the complexity of the real world environment and its rich physical affordances in designing contextual mobile learning activities. Essentially, what add value to contextual mobile learning lies not only in the provision of sophisticated technological tools, but also, in designing learning activities that allow learners to leverage on the richness of the physical context interacting with the environment and with each other to construct knowledge.

In recent years, we have witnessed policy initiatives both at the national and institutional levels to provide more affordable and accessible mobile devices to learners. In addition, there have been increasing interests about how to connect learning experiences in and out of school contexts through the mediation of mobile technology and applications. Field trips or outdoor learning supported with mobile technology is one form of situated learning that schools are exploring to provide students with rich, authentic experiences. Prior research studies on the integration of mobile devices in field trips or outdoor learning activities, however, seem to focus on human-mobile device interaction and/or the mediation of mobile applications for learning effectiveness. Few explore and examine the relationship amongst activity design and discourse in the context of the rich physical affordances, to bring about the desired learning outcomes.

This study, therefore, aims providing some insights about how the three intricate dimensions—activity design, physical affordances, and discursive practices—are unfolded in the situated context of a outdoor mobile learning trail, ultimately drawing implications on the design of contextual mobile learning activities for promoting meaningful collaborative learning experiences. Primarily, we are interested in the potential impact of the physical setting on activity and discourse types and consequentially, how the provision of facilitation and technological tools can mediate this process. Hence, this research study revisits the relationship between activity-structuredness and discourse in the context of mobile learning by exploring the missing dimension—the richness of the physical affordances in a mobile learning environment. The structuredness of activity design may not be the only factor framing interaction patterns. Hence, we are inclined to hypothesize that the physical affordances in the real world platform could possibly create *cognitive disequilibrium* [22], thereby yielding some traces of higher-level critical thinking, diversity in perspectives and collective convergence of shared understandings. In particular, our research inquiries read:

1. To what extent does activity design and activity structuredness impact discourse moves in a mobile learning context?
2. How does the interaction with the physical affordances of the outdoor learning context impact activity structuredness and activity discourse?

3 Methodology

3.1 Research Context

This research study was carried out at one of the future schools in Singapore. The Future School project is the initiative by the Singapore Ministry of Education to select exemplar schools that demonstrate a high level of technology integration across all subjects and levels. As such, the research school also emphasizes seamless and pervasive use of technologies in the teaching and learning process. With the implementation of 1:1 computing, all teachers and students are equipped with MacBooks, and the school campus is fully technology-enabled.

The research study presented in this paper is part of the three-year design-based research where we explored the

TABLE 1
Overview of Activity Design and Activity Structuredness and Characteristics

Station	Activity type	Description of activities	Desired learning outcomes
Yellow Station	Performative	*Activity 1:* Measure and calculate the gradient of the slope at 3 different sections of the beach and rank the slope from the gentlest to the steepest.	To understand the impact of physical forces such as erosion and deposition on the steepness of the beach.
	Performative and Knowledge generative	*Activity 2:* Interview tourists to find out why they picked Sentosa as a holiday destination and what they think can be improved for Sentosa as a tourist attraction.	To collect qualitative data through primary resources such as face-to-face interviews for analysis and evaluation of issues.
Red Station	Performative	*Activity 3:* Capture a picture along the coastal area and annotate five physical features: beach, island, observation towers, sea & suspension bridge.	To capture photo images and label its features as part of the process of data collection.
	Performative	*Activity 4:* Calculate tower height using trigonometry.	To estimate the height of both physical and human features & to relate the actual features seen on ground to the representation on topographical maps.
	Performative	*Activity 5:* Identify, capture a picture of the ridge and annotate the physical feature.	To differentiate between physical features.
	Performative and Knowledge generative	*Activity 6:* Identify important industries near Sentosa and state their significance for the Sentosa establishment.	To ask geographic questions, acquire and analyse geographic information.
Green Station	Knowledge generative	*Activity 7:* Design thinking with a focus on the beachfront area of the Sentosa island in terms of its attractions, accessibility and amenities. Identify a problem area and propose solutions, following the four fundamental steps of design thinking—brainstorm, share, categorise and solutioning.	To analyse, synthesize and evaluate real-life situations, in a systematic manner.

integration of the mobile technologies and applications into the design of mobile learning trails in the teaching of integrated humanities (i.e., History and Geography) both in and out of the classroom (see [35] for more details). In this paper, we present the design and implementation of the mobile learning trail held at Singapore Sentosa Island, where the Secondary one students applied and contextualized geography knowledge and skills learned in the classroom setting in the real world platform.

3.2 Mobile Learning Trail Structure and Activity Design

The Geography mobile learning trail was conducted at Sentosa Island, in March 2010. The duration of the mobile learning trail was approximately 2.5 hours. The activities in the mobile learning trail were co-designed by the research team and collaborating teachers over a period of one and a half months. The team had weekly design meetings in the school to discuss issues such as curriculum foci, desired learning objectives, learning activities, and technological platforms. Visit to the mobile learning trail site was also pivotal in the co-design process. The team met at the Sentosa trail site to determine the learning stations, the activity type and the activity structuredness, appropriate to the physical affordances of each learning station.

For the geography mobile learning trail, three main activity stations, named Yellow, Red, and Green, were identified along Sentosa's coastal areas spanning from Siloso beach to Palawan beach. Table 1 presents an overview of the type of activities designed at these three stations for the mobile learning trail.

Two key considerations drive the design and execution of the mobile learning activities. Firstly, the learning activities should provide students with an authentic platform to apply their acquired geography skills and knowledge in a real world setting. Secondly, the activities ought to set the stage for in-situ collaborative learning and collaborative meaning-making among students in the course of interaction with and within context. Hence, the on-site activities seek to maximize the presence of a *real world* platform, engaging students in meaningful knowledge building where "the process of learning is informed by sense of place" [36].

In examining activity design and implementation, we are particularly interested in the nature of activity types in terms of structuredness, which can be broadly categorized in three types. First, we define well-structured activities as *performative activities* where learning paths to complete an activity is rather fixed and procedural, leaving relatively little room for negotiation, judgment and conflict among group members. Measuring and calculating gradients of slopes (Activity 1) is an example of well-structured activities, as students apply procedural skills learned in classroom lessons to solve the activity. Second, we refer ill-structured activities to *knowledge generative activities* where the course of learning focuses on generating, communicating and co-constructing ideas. For instance, the design thinking activity at the Green station (Activity 7) falls into this category of knowledge generative activities since the nature of activities does not lead to one single answer or learning path; instead students need to propose feasible solutions in the consideration of multiple dimensions. Lastly, the nature of activities can also see a *combination of both performance and knowledge generation* as the case of Activity 2 at the Yellow station where students need to generate interview questions and perform an interview with tourists.

At each station, groups of 3-4 students worked collaboratively on these activities. No specific roles among the group members were pre-assigned by the teachers. To promote independent collaborative learning, the student groups were supported by two types of facilitation, explained in the next section.

3.3 Facilitation & Technology Mediation

As aforementioned, both facilitation and technological tools assume a supporting role in a process-oriented methodology. In the context of mobile learning environment, facilitation is deemed a necessary intervention to assist learners to construct meaning in their interaction with the real world context [37]. In the mobile learning trail, two modes of facilitation were put in place: *facilitators* and *technology mediation*. First, trained facilitators were assigned to all three activity-stations, and teachers were also present to monitor students' progress. Scaffolding by facilitators was a built-in measure to assist students in their collaborative undertaking by providing them with activity-oriented questions and necessary prompts that build on students' contributions to charter the course of their discussion.

Next, for technology mediation, we gave due considerations to its relevancy in relation to activity and the physical environment, and of equal significance is that the appropriation of technology should render the rightful support to bring about the desired learning outcomes [38]. Each team (max. four students) had a MacBook (laptop) throughout the mobile learning trail of approximately 2.5 hours. On the appropriation of mobile devices and applications, we selected a laptop as a main mobile device in this mobile learning trail since all students were equipped with MacBook with the implementation 1:1 computing in the school. The students were also allowed to use any other mobile devices such as mobile phones and digital cameras for carrying out the trail activities.

A web-based platform (see Fig. 2) was developed to host all trail activities providing organisational and procedural support for students to carry out their activities. In the web-based platform, students were able to upload their findings and collated artifacts onto their teams' respective web pages. Each group was given a password to log onto the system and a set of coordinates to locate the stations with the help of Google Maps. Embedded technological tools in the web-based platform such as Google Maps, image annotation tool, audio and video recoding applications, serve to empower students to assume greater ownership of their own learning in a mobile learning context. Students were relatively familiar with the use of MacBook as their main learning device and the use of the embedded applications to assist them on location mapping and navigational skills (e.g., grid referencing, directions, bearings, distance and scale).

Fig. 2. Web-based platform.

3.4 Participants

In this study, we employed a naturalistic case study method [39] to unpack the relationships among activity design and discourse types in the context of mobile learning. To examine more closely how students co-construct ideas for each activity type, our study focused on three groups of four students each. The selection of groups was randomly made in consideration of gender and academic ability since the teachers expressed some concerns whether the mobile learning trail requiring complex problem solving and the use of several technological applications has any bearing on academic ability and gender. Hence, we selected three groups with a balance of gender and academic ability levels: Group 1 all-girls and mixed ability, Group 2 all-boys and mixed ability, and Group 3 mixed gender and high ability.

3.5 Data Collection and Analysis

The conversation and interaction of group members for all activities on the mobile learning trail were video- and audio-recorded and transcribed for analysis. Each student was given a digital audio recorder attached to his/her body. One researcher was assigned to each group to video-record the undertaking of the learning activities at each station, and another researcher to take field notes.

To analyse the students' interactions and knowledge construction process, all verbal data of the students (73 pages in total) was transcribed and analysed with respect to two key dimensions in the knowledge construction process, namely, *the epistemic* and *the social*. We adapted Pena-Shaff's framework [40] for analyzing discourse where she subsumed the eight categories on knowledge construction proposed by Pena-Shaff and Nicholls [14] into the epistemic and social dimensions surfaced in Weinberger and Fischer [23]. We found that while the frameworks were originally used to analyze online discourse, the coding categories are general enough to be applied in face-to-face discourse. Further, the framework was premised upon a social constructivism theoretical framework consistent with our theoretical stance on collective knowledge construction.

Pena-Shaff and Nicholls [14] posit that learning environments in the light of a constructivist framework should

TABLE 2
Coding Category System for Knowledge Construction

Dimensions		Code Category and Description
Epistemic Dimension	Construction of Problem Space (retell rather than interpret)	*Elementary Clarification (ECL):* Observing or studying a problem identifying its elements, and observing their linkages in order to come to a basic understanding
	Construction of Problem and Conceptual Space and Relationships between both (main activity in problem-oriented learning environments)	*Question (QS):* Establishing relations between the problem and the conceptual space *Reply (RP)* *In-depth Clarification (ICL):* Analyzing and understanding a problem which sheds light on the values, beliefs, and assumptions which underlie the statement of the problem
	Construction of Relations between Problem and Conceptual Space	*Interpretation (IN)*
	Some Epistemic Dimension	*Evaluation/Judgment (EV/JD)*
	Statements not conductive to knowledge construction	Clarification without grounds; inappropriate use of theory/ concepts, arguments with no ground, remarks on organization matters (*non-KC)*
	Non-epistemic activities	Social comments not related to discussions (*non-EP)*
Social Dimension		*Externalisation (EX):* Discussions typically start with externalization/ Explain what they know *Elicitation (EL):* Receiving information from the learning partners learning partners as a resource *Quick consensus building (QCB)* *Integration-oriented consensus building (ICB)* *Conflict-oriented consensus building (CCB)*

present learners with opportunities "to reflect on the content under study, to negotiate meaning with the self (reflective activity) and with others, and to apply the knowledge learned to real life situations" (p. 245). Fischer et al. [41] define the *epistemic dimension* as the activity discourse where participants undertake knowledge construction activities, and emphasis is given to the *content of the contributions* of the participants. More importantly, Weinberger and Fischer [23] assert that "different activity types require different epistemic activities" (pp. 74-75) to promote knowledge construction, and they surface three key epistemic activities for knowledge construction activities featuring (a) the problem space, (b) the conceptual space, and (c) relations between conceptual and problem space. Of equal significance in the analysis of collaborative learning discourse is Weinberger and Fischer's proposition of the *social dimension* where they posit that the social mode of co-construction describes how learners response to and/ or build on the contributions of fellow participants in the course of solving an activity. To which, they proposed five categories—(a) externalization, (b) elicitation, (c) quick consensus building, (d) integrated-oriented consensus building and (e) conflict- oriented consensus building.

For the epistemic activities, we found it necessary to distinguish elementary from in-depth clarification statements where the former depicts participants who merely retell a problem statement at the surface level showing basic comprehension of the problem case. Here, we hope to make a distinction between surface processing and in-depth processing skills for a neater evaluation [42]. Next, we included a category for non-epistemic activities to indicate small chats and social comments that are not related to activity content. Also for the social dimension, instead of subsuming the five categories (externalization, elicitation, quick consensus building, integrated-oriented consensus building and conflict-oriented consensus building) under indicators, we retained them as distinct categories and state their corresponding indicators as exemplified by Weinberger and Fischer [23]. Table 2 features the revised coding category system based on Knowledge Construction on Pena-Shaffs' [40] categories and indicators, and Weinberger and Fischer's [23] dimensions.

3.6 Coding Schema and Unit of Analysis

The group interaction discourse of completed activities for all three groups at the various activity stations was selected for analysis in this study. The number of completed activities varies from station to station, ranging from minimum two activities to maximum four activities. As such, the corpus of transcribed verbal data at the different activity stations was segmentised first according to the different activities at each station, and thereafter, according to semantic features such as topics, discussion threads and ideas. Chi [43] argues that it is more meaningful using semantic boundaries to determine the unit of analysis since an idea may require a few sentences to put across; moreover, similar ideas could be surfaced several times by team members who are more vocal. We found this particularly true of face-to-face collaboration where tracking the development of the interactions to trace evidences of collective knowledge construction is necessary. Hence, each segmentised unit of analysis in our study, depending on the discussion thread and topic, could contain a single or several categories. To achieve reliability, the first author undertook two more rounds of re-coding for all three participant groups. A second coder was also deployed, and an inter-rater reliability of 0.712 (Kappa coefficient) was achieved. In general, a Kappa value of 0.7 above is acceptable.

4 Findings

This section addresses the aforementioned key research inquiries—chiefly to examine the impact of activity design

TABLE 3
Frequency of Occurrences of Discourse Types According to Activity-Type

Group 1

Activity type & structure	well-structured ←						→ ill-structured
	Performative				Performative + Knowledge Generative		Knowledge Generative
	Activity 3	Activity 5	Activity 4	Activity 1	Activity 2	Activity 6	Activity 7
Epistemic dimension							
ECL	2	2	1	4	0	0	0
QS	1	1	0	0	1	2	3
RP	3	0	4	4	1	5	3
ICL	0	0	0	3	1	0	3
IN	0	0	1	2	2	2	8
EV/JD	0	0	2	3	3	0	5
non- KC	3	3	3	3	4	0	6
non-EP	2	0	4	2	0	0	1
Social dimension							
EX	2	2	6	12	1	3	3
EL	3	3	5	12	3	4	4
QCB	3	2	4	10	1	1	3
ICB	0	0	1	0	0	1	5
CCB	0	0	1	2	2	0	2

Group 2

Activity type & structure	well-structured ←				→ ill-structured
	Performative			Performative + Knowledge Generative	Knowledge Generative
	Activity 3	Activity 5	Activity 4	Activity 6	Activity 7
Epistemic dimension					
ECL	0	1	2	0	2
QS	1	1	3	1	5
RP	2	1	5	3	3
ICL	0	0	3	0	2
IN	0	0	1	1	7
EV/JD	0	0	1	0	6
non- KC	2	0	2	1	8
non-EP	0	1	1	0	0
Social dimension					
EX	3	2	5	1	6
EL	3	3	5	2	6
QCB	2	2	3	0	3
ICB	0	0	0	1	3
CCB	0	0	1	0	5

Group 3

Activity type & structure	well-structured ←			→ ill-structured
	Performative		Performative + Knowledge Generative	Knowledge Generative
	Activity 3	Activity 1	Activity 2	Activity 7
Epistemic dimension				
ECL	0	4	0	0
QS	0	2	1	1
RP	4	5	3	3
ICL	0	1	0	2
IN	0	2	2	4
EV/JD	0	1	2	3
non- KC	8	3	4	4
non-EP	7	0	0	2
Social dimension				
EX	6	6	3	3
EL	6	6	3	4
QCB	2	6	2	2
ICB	0	0	1	1
CCB	0	1	1	2

Note: ECL= Elementary Clarification, QS= Question, RP= Reply, ICL= In-depth Clarification, IN= Interpretation, EV/JD= Evaluation/Judgment, Non-KC= Statements not conductive to knowledge construction, Non-EP= Non-epistemic activities, EX= Externalisation, EL= Elicitation, QCB= Quick consensus building, ICB= Integrated-oriented consensus building, CCB= Conflict-oriented consensus building.
The ordering of the activities is based on the degree of structuredness ranging from more to less-structuredness.

on discourse, tracing the characteristics of a discourse that shows indicators of collaborative knowledge construction, and to review the relationship between activity-structuredness and activity discourse in the context of a mobile learning environment, endowed with rich physical affordances. We shall begin with an overview and a comparison of the occurrences of the discourse types across all activity stations for all three groups before proceeding to discuss the significance of the physical affordances in a mobile learning environment in understanding the relationship among activity type, activity structuredness and discourse.

4.1 A Comparison of the Occurrences of Discourse Types

The frequency of occurrences of statements for all activity-discourse according to the category system is presented in Table 3 for all groups at all three activity stations. As mentioned earlier, only the conversational discourse of completed activities was coded, thus for the Activities 1 and 2 at the Yellow station, only findings of Group 1 and Group 3 are reflected, and for Activities 3 to 6 at the Red station, Group 3 completed only Activity 3 out of the four activities assigned. All the groups managed to complete the Activity 6 at the Green station.

A comparison of the occurrences of statements across all three stations reveals an unequal distribution of statement types. The bulk of the utterances at the Yellow and Red stations for all three groups falls chiefly into basic clarification, reply, externalization, elicitation and quick consensus building categories. Clarification statements in the epistemic dimension remain mostly at the elementary phase except for Group 1 and Group 3, which manage to raise some in-depth discussion during Activities 1 and 2 at the Yellow station. For the Red station, there are zero occurrences of in-depth clarification, interpretation, judgment/evaluation, integrated-oriented and conflicted oriented statements for

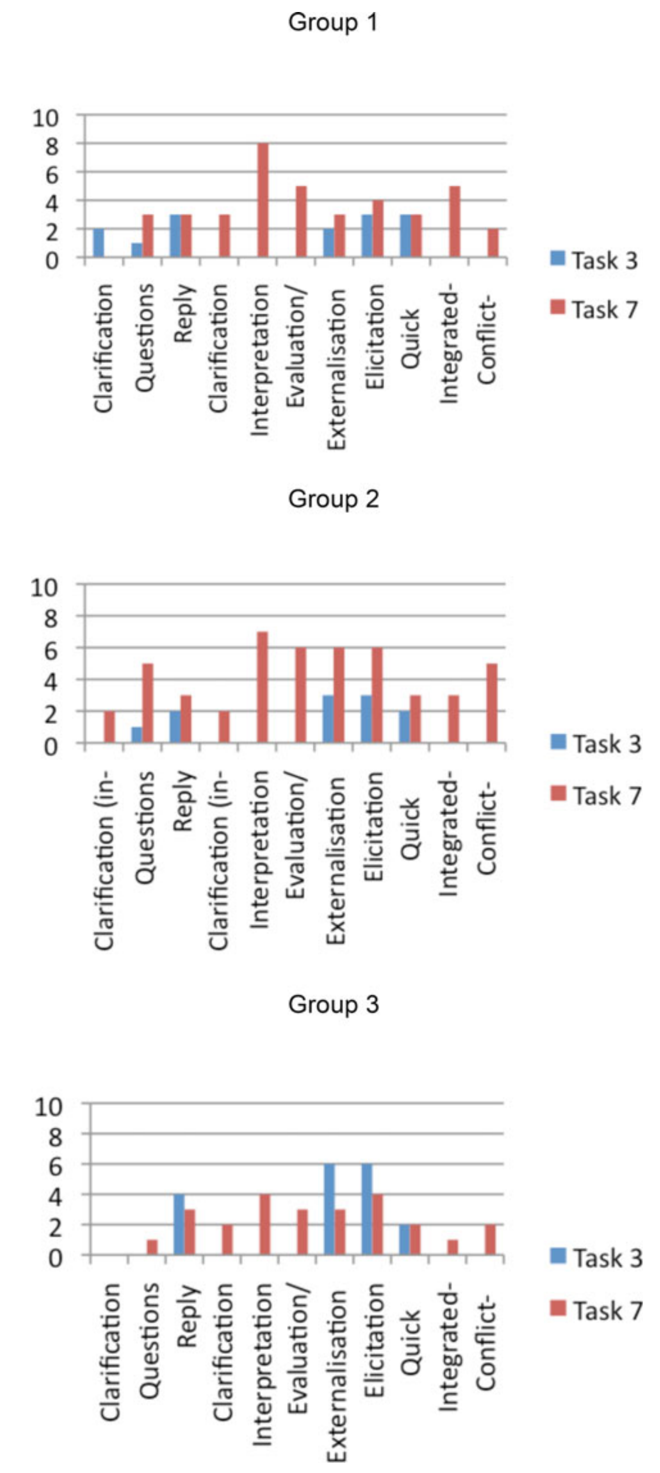

Fig. 3. Discourse frequency charts between performative activity (Activity 3) and knowledge generative activity (Activity 7).

Activities 3 and 5. This unequal distribution of occurrences of statements becomes more apparent when one compares the activity-discourse between the Red and Green stations for all three groups. The activity-discourse at the Green station sees marked improvement in the occurrences of interpretation and judgment/evaluation across all three groups. Similarly in the social dimension, there are also reportedly fewer externalization and elicitation statements. Instead, we saw some instances of integration-oriented and conflict-oriented statements. Statements not conductive to knowledge construction also witnessed a noticeable decline. Learners were more engaged in-depth discussions that require them to consider one another's contributions, give comments and propose suggestions in the course of arriving at a consensus.

4.2 Impact of Activity-Design on Discourse Types

We argue that one reason to explain the above phenomenon lies in *the nature of activity and the measure of its structuredness*. Activities 3, 4 and 5 at the Red station (refer to Table 1 activity descriptions) are chiefly application and procedural (well-structured), which require learners to transfer acquired geography knowledge and skills into real world situations. Hence, in the social dimension, statements made were predominantly externalisation to verbalise what they already knew about a specific application or problem-solving process, and likewise, elicitation statements to seek affirmation of known procedures. Learners were also inclined towards quick consensus building to proceed with activities since they were relatively familiar with activity requirements and protocol. Likewise, we could also conclude that the activity-type and its degree of structuredness also account for the occurrences of basic clarification, question, and reply statements in the epistemic dimension.

Comparatively, the activity on design thinking at the Green station (Activity 7) allows more space for collective knowledge generation and construction. To visualize the difference between performative and knowledge generative activities (on a continuum from well-structured to ill-structured), we selected Activities 3 and 7 and plotted the frequency of discourse types for each group in Fig. 3. The bar graphs show that the content of the contributions from the learners indeed shows an increase in more in-depth clarification statements, evaluation, integrated-oriented and conflict oriented statements for Activity 7 across all the three groups than those for Activity 3.

Our findings and analysis further accentuated that different epistemic activities are also likely to dictate the learners' activity-discourse. This inherently implies a close relationship between the types of epistemic activities and the social modes of co-constructing and advancing knowledge. In the social process dimension, our case study also shows that pure application and procedural activities tend to yield more externalization, elicitation and quick consensus building, as surfaced in the conversational discourse for activities at the Red and Yellow stations. Discussion often remains at the elementary level of acknowledgement and affirmation of known procedures. And in the epistemic dimension, there are also significantly fewer evidences of a rigorous interaction in the sharing and improvement of ideas amongst learners to construct and advance knowledge. It is apparent that activity type and its activity-structuredness have a definitive bearing on discourse moves: both the scope and intensity of the discussion. This also has significant implication on the engagement level of the learners: the intensity of the interaction with one another and *with the affordances* of that specific mobile learning environment.

4.3 Impact of the Physical Affordances on Activity-Structuredness and Discourse Types

The essence of collaborative mobile learning, embodied in the constructivist approach, epitomizes learner's construction of meaning on their own and with others, and the application of knowledge in *real world contexts* where students are presented with opportunities to think about the object and subject of study. As aforementioned, various research studies have affirmed that activity structuredness do incur a definitive impact on activity discourse, determining both the direction and depth of discussion. Whilst this holds true as exemplified in the above segment on the impact of activity design on activity discourse, yet another dimension of our findings runs contrary to the prescriptive deduction of the relationship between activity-structuredness and the consequential production of interaction discourse, in that, *well-structured problems yield higher critical thinking discourse type and vice versa*.

A review of the activity discourse for Group 1 and Group 3 at the Yellow station activity 1 and Group 1 and Group 2 at the Red station activity 4 (see Table 3), shows that this activity-type, though well-structured (mainly skill-based and application) generated some in-depth clarification, interpretation and evaluation statements in the epistemic dimension, as well as, integrated and conflict-oriented consensus building in the social modes of co-construction.

We attribute this phenomenon to *the affordances of in-situ learning*. Albeit that the nature of activities may not have changed drastically from the usual mundane procedural activities which might have been accomplished in the four walls of a classroom, the presence of the real world physical environment certainly presented a different facet, where learners are confronted with the real world platform to translate their acquired geography skills and knowledge into practice. This is evident in the activity discourse of Group 2 at the Red station. The students were uncertain in locating the southern most point and next, they were baffled with the correct way to measure the distance. The vastness of the real world environment as compared to measuring the statue in the school compound poses unforeseen variable and creates the need to renegotiate meanings and shared understanding, as seen in Except 1 below.

Excerpt 1: Group 2 at Activity 4 Red Station where the group had to locate the tower and to measure the distance between their current position and the tower.

Student N: Find the far away. Measure the angle of one of the towers, at the southern point of the...
Student P: Which is this...
Student N: Southern most point. Where is south?
Student J: There there there.
Student N: That one. You have to measure which one?
Student J: That's the tower.
Student N: So you have to point at the top, eh, point at the top.
Student P: Which one?
Student N: Align yourself at the starting of the bridge. Here, here, around here, around here.
Student J: I need to find my 90 degrees first.
Student N: Ok. Did you see the top? Ok, ok, no no.11 degrees?
Student V: 80 or ?
(Group proceeds to calculate distance)
Student N: Calculate the distance between your position and the tower.
Student P: What is the height?
Student N: Measure from here or here. It was over here.
Student P: Use Google maps.
Student N: Start from where you know?
Student J: Ok, what is the distance? Uh, then how are we going to find the gradient?
Student P: Ok, check Google. From the point that you measure.
Student P: How do you find the distance? Ok, go down, go down.
Student N: Remember what Sir taught us?
Student J: But you are supposed to use that method.
Student P: That time they didn't use.
Student V: They used these.

This student discourse demonstrates that well-structured applicational activity becomes *ill-structured* for the interaction with the real world affordances presented some *unforeseen contextual variables* where students found the application of known formulas to calculate the tower height and distance was no longer as clear-cut, and the problem-solving process necessitated a few rounds of collective review of ideas and consensus. Therefore, the seemingly straight-forward application activities such as the measuring and ranking of the gradient of slopes at the designated beach sections, and calculating tower height at the observation point saw unusual engagement in the activity-discourse and greater collective knowledge construction.

5 Discussion

This study investigates the relationship between activity design and discourse types on a mobile learning trail. First, we were interested to gain insight into the relationship between activity-type and its structuredness and discourse moves in an outdoor learn setting. Second, we explored the impact of physical affordances, a missing dimension in predicting the relationship between activity-structuredness and activity discourse. It should be noted that our aim is not to claim for direct causal-relationships between activity design and discourse patterns, but rather, to provide in-depth views about the designing of the mobile learning trail, leveraging both on the physical affordances of the environment and technological mediating tools, and its interwoven relation to interaction in the course of collaborative learning in an outdoor learning scenario. To this end, the three-prong approach (F.A.T) serves as a conceptual framework to guide the design of meaningful contextual experiences in mobile learning environments. Essentially, it gives focus to the three critical constructs: activity types, technology mediation and facilitation, which could frame and shape learners' interaction with one another and with the physical resources of the learning setting.

Verbal data captured from the three groups of secondary students was content-analyzed according to the coding scheme of knowledge construction, and the comparison/contrast method was used to unpack the complex relationship between activity design and up-take. The nature of activity was categorized into performative, knowledge generative, or combination of both, based on its structuredness in relation to the course of learning and expected learning outcomes. The three groups of students carried out seven activities ranging from well-structured performative activities to ill-structured knowledge generative activities in the authentic context of a geography mobile learning trail.

Overall findings provide accounts supporting the close relationship between activity types and discourse types. Two key findings were surfaced. First, when groups participated in the activities that afford space for knowledge generation, the occurrence of interpretative and evaluative discourse appears to be high. On the other hand, when groups participated in performative activities that are rather fixed and procedural, groups' discursive practices tend to be clustered around the sequence of question-answer and quick-consensus building. However, this is not to say that performative activities are not desirable in collaborative learning practices.

Second, performative activities do play significant roles—supporting learners to internalize and externalize their knowledge and skills when activities embed unforeseen variables and resources with the physical environment. Specifically in the context of outdoor mobile learning, transferring learned classroom knowledge and skills into authentic contexts is not a straightforward undertaking. Further, as exemplified in our analysis, contrary to the empirical studies on ill-structured activities and higher critical thinking discourse type, there remains a high possibility for well-structured activities to yield higher order critical thinking and more collective negotiation and re-convergence of shared understanding, owing to the learners' interaction with the contextual variables of the specific outdoor learning environment.

This intriguing finding also questions the general assumption of linearity from well-structured to ill-structured activity. Our contention is that the assumed linear progression of activity-structuredness and discourse moves warrants a review for an outdoor mobile learning scenario, endowed with rich physical affordances. The design of an activity and the degree of its structuredness, and the assumed desired learning outcomes, is still very much subjected to the affordances of physical and social resources in the mobile learning environment—a missing dimension that could be possibly overlooked and understudied.

Another explanation for the second finding arises from the notion of *cognitive disequilibrium*. According to Cho et al. [22], "the more cognitive disequilibrium a task elicits, the more students will engage in asking questions about the task" (p. 115) and questioning forms a critical determinant in peer interaction and discourse moves. Further, they hypothesize a triangulated correlation amongst activity types, question types and response types. Here, they posit that activity types are likely to exert an impact on question types, which consequently, will shape the discourse and interaction patterns of the learners. Reiterating the affordances of the physical environment in the mobile learning trail, our findings and analysis indicate that cognitive disequilibrium can occur even when learners undertake well-structured activities in an authentic learning setting. Here, the rich physical affordances cause a cognitive disequilibrium for the real world environment, and pose multiple possibilities and perspectives for the seemingly easy procedural and application activity. This is evident as aforementioned, Group 1 and Group 3 at the Yellow station Activity 1 and Group 1 and Group 2 at the Red station Activity 4 (see Table 3) took a longer time than usual, to review, reflect and reconnect concepts and skills learnt in the four walls of the classroom.

In essence, the transfer and application in the real world setting is contingent on the physical affordances of that specific learning setting. Learners became uncertain at applying a familiar formula of measuring height using trigometry and gradient of slope though they had "practised and applied" those formulas at the school compound. Here, in a mobile learning context, confounded by the physical affordances, learners had to exercise more critical thinking in the course of finding and affirming solutions collaboratively.

These research findings carry significant implications on the pedagogical approach in mobile learning contexts. In designing mobile learning trails, we gave emphasis to the design of activities that leverage on the '*sense of place*' and its affordances, to bring about the desired discourse. We provided a relatively good mix of activity-type ranging from well-structured to ill-structured to enable students to apply procedural geography skills and knowledge, as well as, to exercise higher critical thinking skills in their interaction with the learning environment. However, the findings hint of a need to rethink the pedagogical value of well-structured activity in outdoor mobile learning contexts and come up with better design of such activities that would induce higher critical thinking and knowledge building discourse type.

6 Conclusion

In this study, we examined the importance of designing activities that incorporate unforeseen contextual variables to promote in-situ learning and collaborative knowledge construction in a contextual mobile learning environment. Foregrounding the core idea of the F.A.T framework which highlights the importance of factoring in the complexity of the real world environment, we designed mobile learning activities that enable learners to leverage on the rich physical affordances interacting with the environment and with each other to construct knowledge. This research shows that the participants of the mobile learning trail realized the complexity of learning in a situated context, in part to the physical affordances, and in part to the activity type at the various stations. Herein lies the pedagogical value of mobile learning beyond the classroom. Such complex situations of application are important learning opportunities for students to learn disciplinary problems through struggles, conflicts and even initial failures.

This study surfaces two critical points about design configurations of contextual mobile learning. One, the dominance of performative activities and highly structured facilitation is likely to reproduce the traditional discourse pattern like initiation-response-evaluation (IRE) in classrooms. Two, in relation to activity-structuredness and activity discourse, its relationship is not as prescriptive in the context of a mobile learning for the presence of the physical affordances of the learning environment could present cognitive disequilibrium, bringing about higher critical thinking where procedural and well-structured activity is no longer as clear-cut and as simplistic as per convention.

However, it would be too superficial and simplistic to assume that these findings attest to all other outdoor mobile learning contexts, content domains, socio-cultural learning conditions and age groups. Also, other forms of qualitative analysis such as interaction analysis may provide greater insights as to how learners (as an individual and a collective body) interact with the physical affordances of the outdoor learning environment and leverage technological provisions to negotiate and converge at shared meanings.

Nonetheless, we believe that this study provides some insights about how the three intricate dimensions—activity design, the richness of the physical learning setting and discursive practices are unfolded in the situated context of a mobile learning trail. The effectiveness of a mobile learning design and its desired learning outcome is a confluence of these three dimensions. Learners' interaction with the physical setting has a profound impact on the way they interpret an activity and their engagement with the activity, and consequentially, learners' discourse. Well-structured activity can become ill-structured in the presence of authentic learning environment posing new and unforeseen variables, which can provoke deep discussion and advance prior existing knowledge.

We proposed a context-oriented and process-oriented theoretical framework as a guide to designing mobile learning activities that enable learners to create new knowledge, re-negotiate meanings, and advance knowledge. Reiterating Goodwin's [8] notion of changing contextual configurations, learners realign their intended course of actions with the emerging artifactual, spatial and social resources in the physical environment. It resonates Sharples et al.'s [8] defining statement on the quintessence of mobile learning that "It is the learner that is mobile, rather than the technology" and the essence of mobile learning is "to understand how people artfully engage with their surroundings to create impromptu sites of learning". As exemplified in the F.A.T conceptual framework, the apportion of facilitation and the appropriating of technological tools play a mediating and supporting role in framing mobile learning opportunities. We argue that a balanced approach in activity design is equally critical in making a transition from doing activities to doing activities with understanding in designing meaningful mobile learning experiences.

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