How artefacts mediate small-group co-creation activities in a mobile-assisted seamless language learning environment?

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Abstract

The rich learning resources and contexts learners experience in their everyday life could play important roles in complementing formal learning, but are often neglected by learners and teachers. In this paper, we present an intervention study in 'Move, Idioms!', a mobile-assisted Chinese language learning approach that emphasizes contextualized learner content creation and meaning (sense) making with their daily encounters. In the study, students used smart phones on a 1:1 basis to take photos of the real-life contexts pertaining to Chinese idioms or conjunctions, made sentences with the idioms/conjunctions, and then posted them onto a wiki space for peer reviews. This paper focuses on analysing students' on-campus face-to-face collaborative learning process. Inspired by the notions of mediation by artefacts and distributed cognition, we derived a novel visualization approach for descriptive analysis of the small-group activities to provide a synoptic view of the process of student artefact co-creation in such collaborative activities. Through our artefact-oriented analysis, we foreground the significance and the potential impact in fostering learners' habit of mind and skills in identifying and appropriating *in situ* resources to mediate their learning activities in any learning space, rather than always being 'dictated' by the resources that the teacher provides with fixed roles to play.

Introduction

From e-learning to mobile learning, one of the most well-known phrases to describe these new advancements in learning technology is 'learning anytime, anywhere'. The mobile technology may enhance student learning whenever and wherever they are motivated to learn (Chan *et al*. 2006; Wong & Looi 2011). Whereas the rise of e-learning a decade ago had resulted in educators' concern of aggravating the digital natives' indulgence in the cyberspace, we argue that through

proper mobile learning design that emphasizes learners' interactions and meaning/sense making with the physical reality (e.g. Rogers & Price 2008; Looi *et al*. 2009; Sharples *et al*. 2009), the technology would instead play a critical role in bringing them 'back' from cyberspace to the physical world.

In a major international synthesis of 1:1 (one device or more per student) technology-enhanced learning (TEL), Chan *et al*. (2006) promote two pedagogical goals for seamless learning. First, with seamless learning, a student can learn whenever they are curious about something unknown, regardless of the learning scenarios. Second, the student may easily switch among different learning scenarios or contexts. Personal mobile devices are seen as promising technologies

suitable for the proposed pedagogical goals. Nevertheless, after several years of relevant studies (e.g. Kerawalla *et al.* 2007; Lai *et al.* 2007; Spikol & Milrad 2008; Looi *et al.* 2010; Wong & Looi 2010), the nature and the potential of seamless learning have yet to be fully explored or holistically posited (Wong 2010; Wong & Looi 2011). One major challenge is that seamless learning apparently goes beyond the four walls of the classroom and bears the potential of mediating learning. In many cases of our learning design, every 'thing', or artefacts, that learners encounter in the learning environment may play pivotal roles in the seamless learning process, suggesting that there is a need to capture how learners interact with artefacts in a seamless learning experience. These learning resources may potentially complement formal learning, but are often neglected by learners and teachers (Coffield 2000).

In this paper, we present an analytic method to analyse the functions of artefacts in mediating learning. The analysis is situated in an intervention study, 'Move, Idioms!', a mobile-assisted Chinese-language learning approach. The design of 'Move, Idioms!' emphasizes contextualized learner content creation and meaning (sense) making with their daily encounters. In the study, students used smart phones (SPs) on a 1:1, 24 × 7 basis to take photos of the real-life contexts pertaining to Chinese idioms or conjunctions, made sentences with the idioms/conjunctions and then posted them onto a wiki space for peer reviews.

In particular, we focus on the students' on-campus face-to-face (f2f) collaborative learning processes. The rationale behind the design of the small-group f2f activities is to motivate and prepare the students for their out-of-school personal learning experiences. The small-group activities can be viewed as a group exercise of what and how the students can individually do in performing their out-of-class learning activities – closely observing and reflecting upon their living environments, associating environmental contexts (or creating contexts with the aid of physical objects or people) with their learnt idioms/conjunctions and generating artefacts for sharing. In analysing the students' learning process in 'Move, Idioms!', we aim to uncover the interplay between students' meaning making and student-generated artefacts. We observe a 'chaining effect' across learning spaces when we highlight the role of artefacts in the meaning-making process – one piece of student work becomes a mediating artefact for the student's or her peers' works in later stages. Such an observation is congruent with Sharples' (2009) exposition, albeit specifically in the context of mobile learning, that 'it may not be possible to determine when the learning begins and ends' (p. 19).

With this, we derive a novel visualization approach for descriptive analysis of the small-group activities of 'Move, Idioms!' that is inspired by the notions of mediation by artefacts and distributed cognition. It is not (yet) our intention in this paper to formalize this approach for more general use, but more to provide a synoptic view of the process of student artefact co-creations. Through our effort of artefact-oriented analysis and visualization approach, we foreground the significance and the potential impact in fostering learners' habit of mind and skills in identifying and appropriating *in situ* resources to mediate their learning activities in any learning space.

Mediation by artefacts

Research findings show that classroom learning mediators include tasks, teacher and peer resources, subject content and semiotic artefacts (e.g. languages, textbooks, PowerPoint and worksheets) (Liang 2009). Artefacts (broadly defined to include instruments, signs, languages and machines) mediate activity and are created by people to control their own behaviour (Nardi 1996). As Stahl (2002) posits, if we adopt a Vygotskian view of mediation by artefacts, then the knowledge construction process can be conceptualized as the construction of knowledge artefacts, involving physical and symbolic artefacts as starting point, as medium and as product.

The notion of mediation by artefacts, as formulated by Leont'ev (1981), accounts primarily for material activity and its outcome in the form of transformed material objects, such as spears, gearshifts and computers. More recently, spoken and written discourse has begun to figure in the lists of mediating artefacts (Wells 2002). Leont'ev (1974) argues, 'A tool mediates activity that connects a person not only with the world of objects, but also with other people' (p. 42). Distributed cognition offers a similar notion: for example, Hutchins (1987) discusses 'collaborative manipulation', the process in what way do we take advantage of artefacts designed by others (and ourselves), sharing ideas across time and space.

Distributed cognition is devoted to the study of the representation of knowledge both inside the heads of individuals and in the world, the propagation of knowledge between different individuals and artefacts and the transformations that external structures undergo when operated by individuals and artefacts (Flor & Hutchins 1991). Combining both social and cognitive aspects, a distributed cognition perspective (Salomon 1993; Hollan *et al*. 2002) suggests that learning should not be perceived as individual cognitive activity, but as a process distributed across individuals *and* artefacts. Therefore, an analysis of cognitive activities that incorporate the functionalities of artefacts will enable us to better understand how learning actually takes place within and beyond our design.

As we turn our attention on analysing learning to the interplay of cognitive or socio-cognitive activities and mediating artefacts, we immediately realize that a major stumbling block is how we define and characterize artefacts. We resonate with Alcock's (2005) interpretative study on young children's co-construction of playful narrative events, motivated and mediated by artefacts. In characterizing artefacts, she treats people (e.g. the teacher who orchestrated the learning activity; a child who used her own body as an artefact to imitate a television character for her peers) as a potential form of artefacts. That echoes Cole's (1996) wider overarching concept of artefacts that people may be used as mediating objects. In addition, the meaning and use of artefacts are structured and transformed through activities. Hence, the term 'mediating artefacts' is not necessarily in the traditional sense of (persistent) man-made objects, but could refer to any element (object or human) involved in the cognitive system of a learning activity, which can be appropriated into a mediating artefact that serves students' learning needs. Such a view is congruent with (Latour 1996) argument that 'to act is to mediate another's action' (p. 237) – both humans and objects mediate, and one can only proceed to action by mediating another's action.

'Move, Idioms!' – theoretical framework and learning experience design

In recent decades, we have witnessed a paradigm shift in language learning theories from behaviourism to a communicative and contextualized learning approach (Salaberry 1996). Nevertheless, as a fundamental component of language learning, vocabulary learning is still often delivered through direct instruction in the classrooms, such as providing abstract definitions and sentences taken out of the context of normal use (Miller & Gildea 1987). Such pedagogical strategies may pose a problem for learning of context-dependent vocabularies, such as conjunctions, idioms and proverbs. The complex nature of such vocabularies is derived from highly context-dependent appropriateness of their usage (Deng 2001). There are many possible real-life contexts where such vocabularies could suitably (or unsuitably but often mistakenly) be used, which are almost impossible to be prescribed in a simple definition (Wong & Looi 2010).

Recognizing both the importance and the limitation of formal, in-class language learning, language learning theorists have been advocating the integrations of formal and informal (Titone 1969; Spolsky 1989) and individual and social (Pierce 1995; Noel 2001) language learning, which mesh well with the notion of seamless learning. Informed by the theories, we developed an iterative, customizable learning experience design of 'Move, Idioms!' (see Fig 1) (Wong *et al*. 2010).

As shown in Fig 1, each 'Move, Idioms!' learning cycle may consist of four types of learning activities. Nevertheless, the combination and the sequence of the activities are customizable from cycle to cycle. In Activity 1 (in-class/campus contextual idiom learning lesson), after assisting students in establishing the initial form-meaning connections of the new idioms through multimedia presentations, the teacher conducts classwide or small-group learning activities, such as facilitating students to take photos in the campus to illustrate the idioms (which is the focus of this paper). Such artefact co-creation activities are conducted with the aim of motivating and preparing the students in carrying out similar activities individually in Activity 2. In Activity 2 (out-of-class, contextual, independent artefact creation), students carry the mobile phones assigned to them 24×7 in order to identify or create contexts in their daily lives that could be associated with the idioms. They then take photos, make sentences by using the idioms to describe the photos and post them onto a class wiki space. In Activity 3 (online collaborative learning), the student artefacts created at Activities 1 and 2 in the current and previous cycles, pertaining to the idioms learnt recently and earlier, facilitate students to carry out peer reviews on the wiki by commenting on, correcting
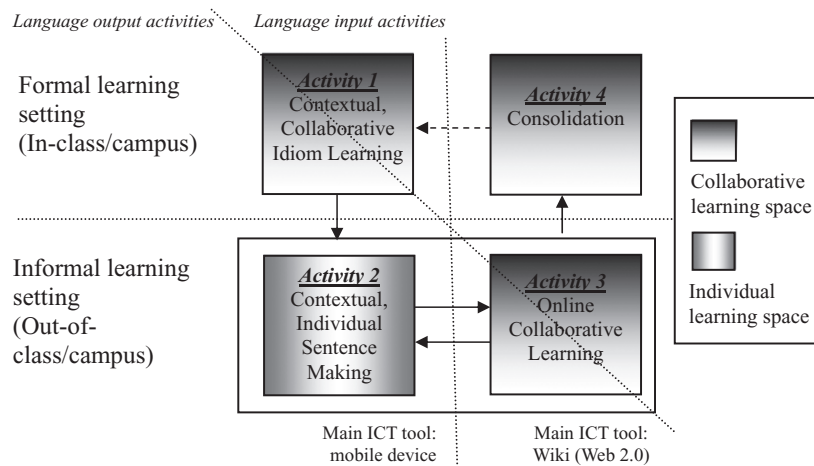
or improving their peers' sentences. In Activity 4 (in-class consolidation), the teacher facilitates small-group or class-wide discussion on selected student artefacts, thereby surfacing contradictory views among the students and challenging their originally constructed linguistic knowledge via the last three activities. Therefore, Activity 4 serves as an enhancement for Activity 3, where the teacher may design scaffolds to improve the students' peer review skills for their subsequent involvement in Activity 3.

In a nutshell, Activities 2 and 3 take place in an ongoing basis and should be blended into students' daily life. Conversely, the instances of in-class Activities 1 and 4 are episodic by nature, and yet they are integral parts of the entire learning experience. These teacher-facilitated activities play the crucial role of preparing the students, who tend to be more accustomed to spoon-feeding-style learning in general, to be more motivated and autonomous in carrying out the more open-ended Activities 2 and 3 at their own time. As this paper focuses on analysing the small-group co-creation processes during Activity 1, we will neither describe findings in Activities 2, 3 and 4 nor the linkage between Activity 1 and the rest of the activities.

The enactment of 'Move, Idioms!'

Our intervention study of 'Move, Idioms!' took place in January–November 2010. A class of 34 primary 5 (11-year-old) students, with mixed abilities in Chinese language (as L2), participated in the study. Each of them was assigned a Samsung Omnia II SP running MS Windows Mobile 6.5, with built-in camera, Wi-Fi

access, Internet browser and English/Chinese text input. The researchers and a group of Chinese teachers co-designed the in-class components of learning activities (Wong & Chin in press) with eight 'Activity 1' and two 'Activity 4' lessons (see Table 1). The activities were then enacted by the Chinese teacher who was teaching the experimental class with 2- to 4-week intervals. With a graphic designer background, the teacher had 8 years of teaching experience and had been one of the InfoComm Technology-enhanced Chinese curriculum leaders in her school. Meanwhile, we featured off-the-shelf mobile-optimized comic animations (http://www.5qchannel.com/) that depict the meanings of the taught idioms during each lesson, which could also be accessed by the students anytime, anywhere.

An artefact-oriented approach to analyse the small-group artefact co-creation activities of 'Move, Idioms!'

In our attempt to unpack the learning processes of the small-group activities during the in-class lessons of 'Move, Idioms!', one particular aspect that comes to our attention is the role of artefacts in mediating learning situated in 'continually moving and re-constructed contexts' (Looi *et al*. in press). In turn, we carried out descriptive analysis [open coding and constant comparisons (Strauss & Corbin 1990)] on the verbatim transcriptions of audio and video recordings, as well as the field notes of student group interactions during all the in-class lessons. The eight student groups were comprised of four to five members each, which were randomly assigned by the teacher prior to the study. We

Table 1. Summary of ten 'Move, Idioms!' in-class lessons (all were 'Activity 1' lessons unless otherwise stated).

Lesson ID No.	
1	Worked in groups of four, students brainstormed and made sentences that utilized the idioms (one idiom per sentence) learnt in this lesson and sketched the scenario on paper worksheet. Students were *not* assigned the smart phones yet.
2	Students were assigned the smart phones after receiving technical training. Worked in groups, they repeated the activity in Lesson 1 except that they were asked to enact the scenarios and took photos within the classroom. They then signed out the phones for 24 × 7 access.
3	Each student group was assigned a particular area within the campus (e.g. canteen, basketball court, ecological garden). They went to the designated area, brainstormed to associate their encounters with their learnt idioms, took photos and made sentences. They were encouraged to make one sentence that utilized two idioms.
4	Each group brainstormed a paragraph that utilized multiple (both newly learnt and previous) idioms. In-class photo taking was not allowed but they were asked to plan for four pictures to depict the group-generated scenario.
5	Each group brainstormed a story with the idioms just learnt in mind, took photos within the campus and then wrote a paragraph that utilized multiple idioms in describing the story depicted by the photos.
6	An 'Activity 4' lesson.
7, 8, 9	Same as 5. For Lessons 8 and 9, they were taught and brainstormed paragraphs that utilized learnt conjunctions instead – although most paragraphs had incorporated some idioms as well.
10	An 'Activity 4' lesson.

adopted the above-stated perspective of mediating artefacts as the analytical lens. The intention of the analysis was to identify various forms of learning support tools and intermediate products, both physical and non-physical, map them into the artefact-oriented perspective and unveil various paths that different student groups had taken to accomplish their learning tasks in different lessons. We engaged student groups to cross-check our analysis through focus group interviews – though we did not use the academic term 'artefacts' and instead asked them to confirm and further elaborate 'things that contributed to or distracted their photo/sentence co-creation activities' that we discovered. Because of the space constraint, we will not go into the detailed analysis, but will present a synoptic view of our findings.

In our analysis, we foreground the interplay between cognitive activities and artefacts (including existing artefacts that mediate the learning activities and the artefacts co-created by the students) in the photo/text co-creation session. By artefact, we refer not only to the student products (photo/text sets), but also the mediating artefacts and emergent, intermediate products involved in their learning processes. Driven by the data and the results of our open coding and constant comparisons, we classified the artefacts identified in the analysis into four categories. The classification is based on the major functionality of each artefact in the learn-

ing process. It is not (yet) definite and may or may not be able to be applied to the analysis of other learning designs or contexts (and perhaps neither exhaustive) – for the time being, we argue that the classification is at least suitable for describing situated learning activities in general. To simplify the analysis, we exclude task-regulating artefacts, such as timers and teacher's disciplinary regulations, but focus on identifying artefacts that are directly contributing to the contents of the students' outcome artefacts during the learning process of 'Move, Idioms!'. The four types of artefacts are below.

Subject matter artefacts

Artefacts that represent the target knowledge to learn and other supportive information and knowledge for the purpose – the idioms and conjunctions themselves (that are linguistic/cultural artefacts), and the example sentences, paragraphs or photo/text sets given by the teachers (digital artefacts – usually in PowerPoint form), as well as comic animations and YouTube videos, to demonstrate the usage of the vocabularies.

Physical artefacts

Physical or environmental tools that mediate the learning activities, such as the ICT tools, the classroom and the campus (and the physical objects available there)
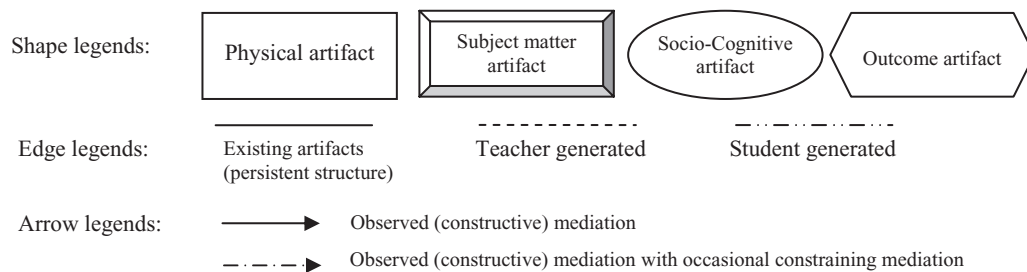
Fig 2 Legends used for diagrams in Figs 3 and 4.

and even people (teachers, students, researchers, guests) who posed for photo shooting.

Socio-cognitive artefacts

Non-physical artefacts generated through socio-cognitive means, such as teacher's verbal scaffolds (VSs) and peer discourses (both are semiotic artefacts), students' *in situ* improvising or emergent strategies to carry out the learning activities, ideas and stories for photo taking and sentence/paragraph compositions, and their shared (evolving) understandings in the associated meanings and linguistic functionalities of the idioms and conjunctions.

Outcome artefacts

The intermediate and target artefacts that the students are explicitly required to generate, including photos and text, peer review comments and peer revised text.

At the first glance, it seems that the first three artefacts are subcategories of 'mediating artefacts' that contribute to or constrain the learning activities (i.e. related to the learning process), while 'outcome artefacts' are products of the activities. In actual fact, there are intermediate outcome artefacts produced at one stage of the activity, which may be transformed into mediating artefacts at the next stage – and they can most likely be classified under 'subject matter artefacts' or 'socio-cognitive artefacts' for 'Move, Idioms!' activities (and perhaps other types of artefacts for different learning designs). That is the reason why we place 'outcome artefacts' in the same dimension with the three mediating artefacts. Furthermore, the classification is more referential than definitive, as our major interest is in what and how artefacts that a learner or a group of learners have identified and appropriated to mediate her/their

learning activities, regardless of which types individual artefacts belong to. Our stance echoes an overarching notion of distributed cognition – that all mediating artefacts within a distributed cognitive system, regardless of their types (physical, virtual, semiotic, cognitive, etc.), are conceptually equivalent agents (Nardi 1996).

Hatch and Gardner (1993) propose a concentric model of the forces affecting a distributed cognition system. The three forces in the model are personal, local and cultural. Our level of analysis with the four types of artefacts being identified fits to the local level of the model. We generated diagrams that depict all the artefact-mediated processes leading to outcome artefact creations as we have observed in the small-group f2f discussions. Because of the word limit, we present only a diagram pertaining to Lessons 5, 7, 8 and 9 (with single photo/sentence sets as outcome artefacts) in this paper. Although it is possible to generate one diagram per student group, we decided to feature one consolidated diagram in this paper for the same reason (word limit). Figure 2 depicts the legends used for generating artefact-oriented diagrams in Figs 3 and 4.

Figure 3 presents an artefact-oriented diagram pertaining to the learning experience of another intervention study, namely, Chinatown 2.0, which was conducted by our research team under a different research project (So *et al*. 2009). We choose this learning experience to illustrate how the readers can comprehend our artefact-oriented diagram, as the learning design is relatively straightforward. It is also our intention to demonstrate the potential of our method to be applied to analyse other types of learning activities. In the study, a group of 12-year-old students embarked on a learning trail in the Chinatown area of Singapore, observed and experienced various historical places of interest within the area, and posted brief geo-tagged notes (location markers) on their initial reflections onto a Google Map
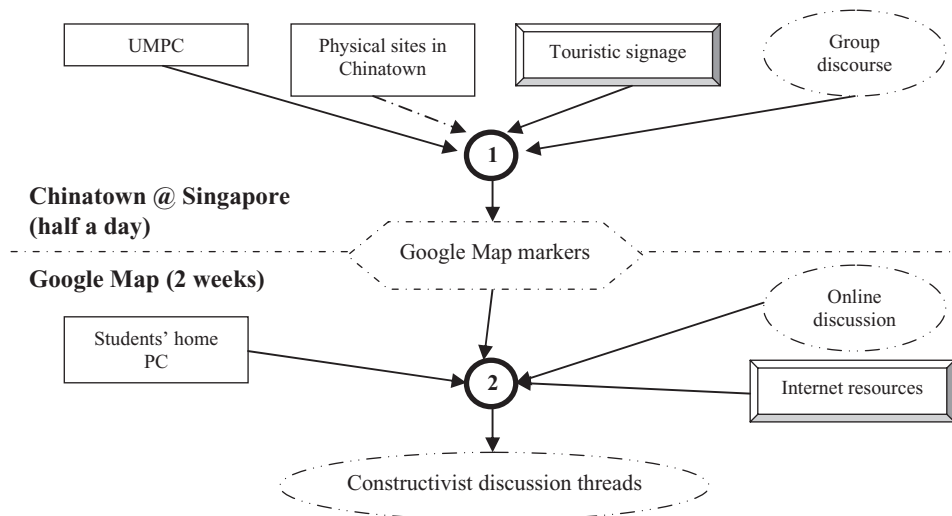
Fig 3 The simplified artefact-oriented diagram of Chinatown 2.0 (So *et al.* 2009) learning experience.

with the mobile devices [ultra-mobile personal computers (UMPCs) assigned to them. In the next 2 weeks after the field trip, the students made use of their home computers to annotate individual location markers on the Google Map in the form of clarification, new factual information, Internet resources, additional questions, etc. that effectively transformed the location markers into online discussion threads.

The arrows in the diagrams represent mediation-outcome relationships. Each numbered node in the diagrams denotes a mini-state, which we refer to as *joint mediation*, of multiple artefacts (linked by incoming arrows) to the student group that results in certain output artefacts (linked by outgoing arrows). For example, in Fig 3, the UMPC, the Chinatown area, the touristic signage and the group discourse (GD) joint mediated the students' efforts of creating Google Map markers *in situ*. We refer to such nodes as joint mediation nodes (JM nodes) (circles labelled '1' and '2' in Fig 3). Note that for any JM node with multiple 'input' artefacts, it is not necessary that all (but can be any combination of) the 'input' artefacts will be utilized in every instance of the joint mediation. The same goes for a JM node with multiple 'output' (outcome) artefacts – not necessarily all but can be any combination of outcome artefacts. The 'multiple outcome artefacts' situation is not illustrated in Fig 3; each state generated a single type of outcome artefact, respectively. The numbers in the JM nodes show the rough sequence of different joint mediations (not definitive, as some groups could have occa-

sionally backtracked to previous states to revise their earlier artefacts) in the co-creation processes. The JM nodes labelled with the same number plus an alphabet (e.g. 1a, 1b, and so on – see Fig 4) represent supplementary joint mediations that occurred in the same mini-state and were likely to be interweaving (or might have happened in some but not all groups). In addition, we identified certain mediating artefacts that occasionally did not play its usual constructive role and instead became distracting or constraining factors to students' learning activities. For example, in Fig 3, the students may occasionally be distracted by fun stuff at the touristic shops that may or may not result in positive incidental learning but definitely dilute their attentions from the core learning goal of understanding the history and culture of Chinatown, hence, the dashed arrow. We refer to them as *constraining mediation*.

The horizontal dashed line that cuts through the centre of the diagram depicts the boundary between two different learning spaces involved in the learning experience. The two learning spaces are labelled in bold font (the physical 'Chinatown, Singapore' and the virtual 'Google Map'), with the rough amount of time spent by the students on each space being stated. Note that the dashed line also cross-cuts the intermediate outcome artefacts 'Google Map markers', which signifies them for being outcome artefacts of the Chinatown field trip and then being transformed into mediating artefacts during the online discussions. Such a representation would further foreground the seamless learning nature
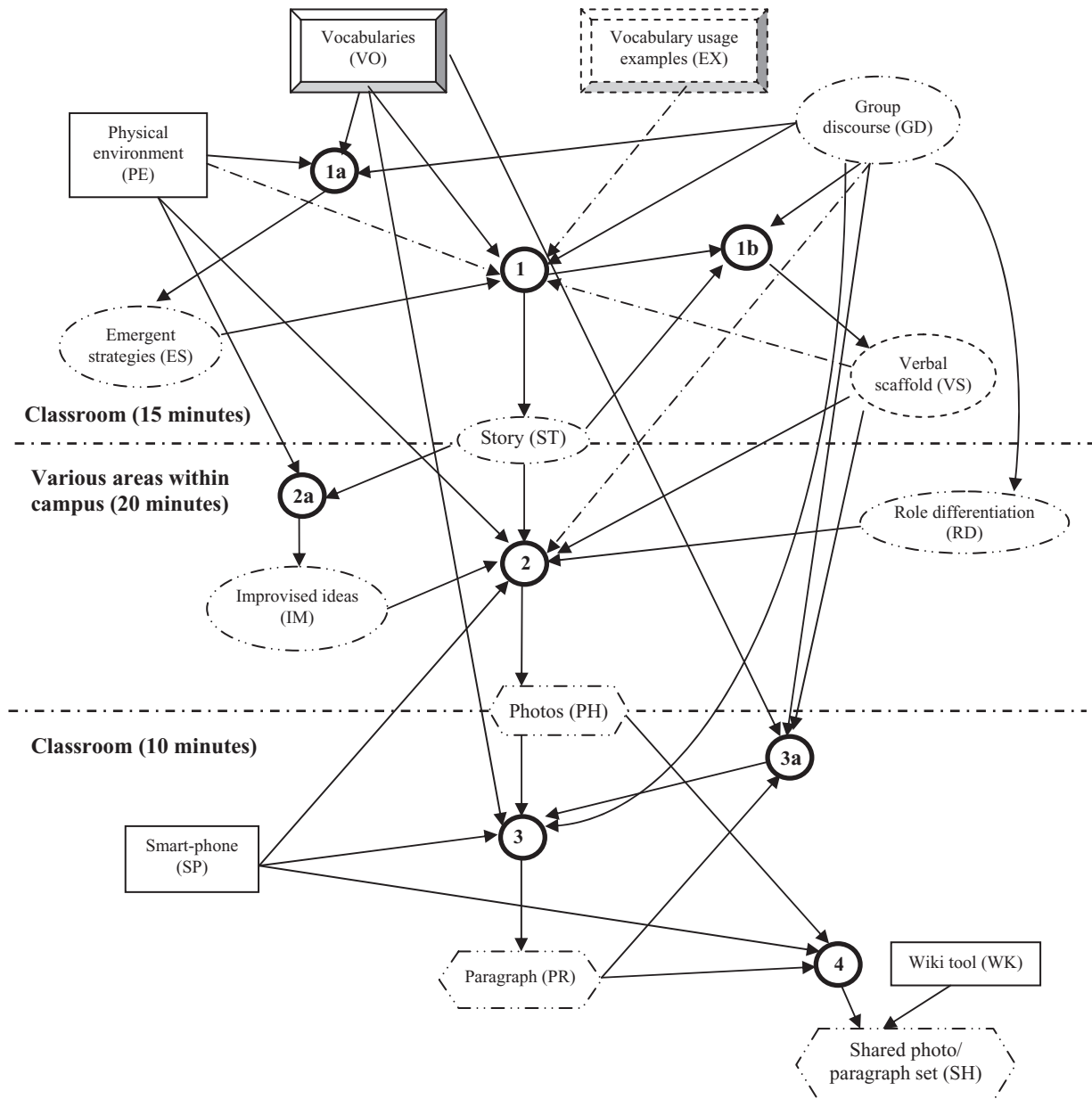
Fig 4 The artefact-oriented diagram of collaborative learning activities in Lessons 5, 7, 8 and 9.

of the learning processes that we analyse in this paper – it is the cross-context generation/usage of certain artefacts that facilitates genuine seamless learning.

It is important to note that Figs 3 and 4 are not meant to be exhaustive representations of all possible aspects. They have arisen from our analyses of the two case studies. For example, revisions of artefacts could happen in other cases, and what an analyst can do is to draw an arrow from the node representing the revised

artefact and loop it back to its preceding numbered node. Such actions did not happen in our studied activities, and therefore are not indicated in the diagrams. We acknowledge the limitation at this point of time and wish to analyse more diversified types of learning process data in the future to discover more patterns and in turn refine our visualization method.

Figure 4 features the artefact-oriented diagrams of the actual 'Move, Idioms!' learning activities that were

generated based on the same principle. The analysis of the learning activities that resulted in the diagrams in Fig 4 will be presented in the next session.

Analysis of small-group artefact co-creation processes in Lessons 5, 7, 8 and 9

The small-group activities in Lessons 5, 7, 8 and 9, enacted with essentially the same learning design, can be divided into four mini-states – story co-generation (the result of the joint mediation of 1; classroom based and lasted about 15 min), photo set co-generation (the result of 2; at various areas within the campus and lasted about 20 min), paragraph co-generation (the result of 3) and wiki page appending (the result of 4; classroom based and lasted about 15 min).

JM nodes 1 and 1a

Fresh from learning new idioms/conjunctions, student groups brainstormed their stories in the class, with the set of vocabularies to use (VO), the vocabulary usage examples (EX), the potentially accessible physical environment (PE; see the next paragraph for elaboration) and the (emergent) GD and teacher's VSs as mediating artefacts. In particular, the vocabulary usage examples (EX) were presented by the teacher prior to the small-group activities in the forms of off-the-shelf idiomatic/ conjunction animations, teacher-created PowerPoint presentations of photo and sentence/paragraph sets or Internet videos. Such digital artefacts inspired or influenced some groups' subsequent storytelling (ST). In many cases, we consider the EX a constraining mediation, as the artefacts constrained the students' creativity – some student groups copied the essential story idea and only made minor changes in the characters or the props. That is, they were not able to apply the learnt idioms in different contexts or introduce new idioms not incorporated in EX, thus limiting their deep learning and internalization of the idioms. However, there were also positive cases where student groups managed to work out stories inspired by the EX but with more enriching contents and utilizations of different sets of idioms.

Even with the 'comfort' of brainstorming (GD) stories (ST) in the classroom rather than *in situ*, students usually took into consideration the accessibility of the PE for their subsequent photo shooting. This might instead become a constraining mediation to their ST as

they had to revise the story and even drop some of the idioms (VO) in mind to satisfy the PE constraints. One example was that a student proposed using the idiom 鸟语花香 that literally means 'birds twitter and fragrance of flowers', but figuratively characterizes 'a fine, beautiful day' in the introductory sentence of their story. The group spent more than 7 min to debate about how tedious it would be to take a photo with both twittering bird(s) and flowers in it within the campus. Even though a member aptly pointed out the metaphorical nature of the idiom and could be used to describe fine weather and pleasant sceneries, with or without actual birds and flowers in the context, his groupmates did not concur and eventually gave up the idiom.

Conversely, for other groups, the PE constraints triggered them to figure out strategies (ES) to overcome those. For example, another group that was similarly stuck in how to portray 鸟语花香 (a fine, beautiful day) had the teacher grant permission to take photos after school. They then worked out a plan of taking four photos and assigned each group member the task to take one of them, with a student who claimed that she could take a photo with birds and flowers from her home balcony assuming the obvious responsibility.

The common misconception on the usage of 鸟语花香 (a fine, beautiful day) was later clarified by the teacher to the class at another lesson. However, we argue that through such learning activities, students were able to more effectively internalize the correct functionality of the idiom after the clarification. Therefore, such a mediating artefact that is seemingly constraining the students' outcome artefact creation in short term may turn out to be conducive in their learning in a long run if the teacher is able to scaffold for 'making errors work for the students and not against them' (Rubin & Thompson 1982).

JM node 1b

During the small-group activities, the teacher was usually 'touring' among the groups to check their progress and provide VSs to improve their contextualized stories (ST) where necessary. Therefore, the VS is usually a product of the joint mediation of VO, PE, GD and/or the work-in-progress ST. However, there were occasional cases where the teacher advised against certain student groups' story ideas for no pedagogical

reason. One possibility was that the teacher's graphic designer background had made her subconsciously more 'interventionist' in students' creative processes and products. We consider that to be another form of constraining mediation that might have distracted the students' creativity. As an illustration, in Lesson 8, which was confined to classroom photo taking, a group came out with the initial story idea (work-in-progress ST) to utilize the Chinese conjunction (VO) '起初 . . . 后来 . . .' (at first . . . and then . . .): – 'At first the neighbours did not know he is a thief; and then they learned about it from the newspaper'. They wanted to take the first photo about the theft in a 'deserted place' but found the classroom too crowded (PE). They explained to the teacher their idea and asked the teacher's permission to let them take the photo in the library. The teacher rejected their idea (constraining VS), perhaps because she did not want them to set the example to the rest of the groups in finding excuses to leave the classroom. Fortunately, after the teacher left, the group adapted the plot and photo taking plan to deal with the classroom-only constraint and later managed to convince the teacher to approve their idea.

JM nodes 2 and 2a

The joint mediation of ST, PE, GD and the SP resulted in the production of the first part of an outcome artefact – the photo set (PH). Prompted by PE, improvised ideas (IM) arose in some photo shooting occasions that resulted in the adaptation of their original ST. Such ideas may involve the use of certain sets (e.g. the library) and props (e.g. putting math and science books, sketch paper, a ruler and a calculator on the desk of an inventor character in the story – all these were contributed by different students) accessible by the students *in situ*. All the group-generated ST required some group members to become actors and enacted the scenario. Therefore, most of the groups were getting self-organized (i.e. role differentiation) with dedicated 'directors' and 'photographers' being appointed (or self-appointed), and they sometimes switched roles between directors, photographers and actors. There were also cases where co-directing and co-photographing took place, and because of the simplicity of the storyline, they still managed to carry out the learning task smoothly.

The SP did not only serve as a productive tool. Occasionally, students checked a photo on the phone display

immediately after shooting, and decided whether a retake was needed to make sure their idea was correctly executed and the idiom association was appropriate. In turn, SP became a cognitive tool (albeit still a physical artefact) to mediate their deeper thinking.

JM node 3

The joint mediation of PH, VO, GP and SP resulted in the production of the second part of an outcome artefact – the paragraph (PR). Unlike during JM node 1 where student groups only worked out rough story ideas (ST) that 'guaranteed' usage of some of the given idioms or conjunctions, this would be the time that they synthesized their ST and photos taken (PH) and threaded the idioms they had in mind together to become a coherent paragraph (PR). In developing their paragraphs, some groups re-looked at the photos taken by different students (although most groups would have appointed an 'official' photographer during JM node 2, some students had taken extra photos when they were not engaged in acting) and replaced or inserted photos to the original photo sets. Additional idioms might incidentally be added to the paragraph. One instance took place in Lesson 5 (see Fig 5), where a group came back to the classroom from photo shooting on a story about basketball playing. A student recalled that her groupmate who played the role of basketball player (and became a PE artefact) was sweating minutes after the shooting started, which was captured by the photos (PH). She asked if 汗流浃背 ('all of a sweat') is an idiom (VO), and a groupmate confirmed that. They decided to incorporate the idiom into the paragraph (PR). We checked with the group afterwards and found out that the idiom was not taught in the present year, but two of the group members recalled that their Chinese teacher in the previous year taught it in the class. The other two members who came from another class with a different teacher had not come across the idiom before, but they now learned it from their groupmates.

JM node 3a

During JM node 3, some groups found it difficult to organize their photos, or organize the idioms and their stories into paragraphs. The teacher was again 'touring' among the groups and provided the much-needed scaffolding (VS). Typically, she looked at the unfinished

一个晴朗的下午，明华和国亮一起去篮球场打篮球。他们玩得很开心，又<u>汗流浃背</u>。国亮正要从明华的手里抢球时，不小心把明华推倒了。明华跌得<u>四脚朝天</u>。国亮赶紧把明华扶起来。明华气得<u>火冒三丈，暴跳如雷，气得脸一阵红一阵白</u>。国亮感到很惭愧，一直向明华道歉。明华决定原谅国亮因为明华知到国亮不是故意推倒他的。他们握手后就继续打篮球。

It was a sunny afternoon. Minghua and Guoliang were playing basketball at the court. They were <u>all of a sweat</u> and yet enjoyed the game. When Guoliang was fighting for the ball from Minghua, he accidentally pushed Minghua to the floor. Minghua fell down on his back with his <u>legs in the air</u>. Guoliang picked Minghua up. Minghua was <u>enraged</u>, <u>furious</u> and <u>hopping mad</u>. Guoliang felt ashamed and kept apologizing to Minghua. Minghua decided to forgive Guoliang because he knew Guoliang did not mean it. They shook hand and resumed their basketball game.

Fig 5 An outcome artefact created during Lesson 5.

paragraphs (PR) and offered ways to organize the relevant artefacts, sometimes with additional or alternative idioms (VO) being proposed.

JM node 4

These were merely synthesizing-and-posting tasks (synthesizing photo and sentence into a complete instance of outcome artefact, and posting it onto the web), although they did append new contents to the relevant wiki pages, i.e. a new version of a wiki page that was a collective outcome artefact was generated.

Discussion

Seamless learning is probably one of the most complex forms of learning as it involves multifacets of learners' daily lives and has the potential of integrating most of the TEL models – digital classroom learning, e-learning, mobile learning, context-aware ubiquitous learning, etc. A holistic seamless learning experience design requires learners not only to interact with other people and instructor-provided artefacts within a relatively closed learning environment (e.g. traditional classroom or e-learning portal), but also with the authentic PE and perhaps the Internet at large, where learners may draw any element or information that they incidentally encounter or recall (based on their prior knowledge or from their past experiences) and appropriate it into a useful mediating artefact for learning. We need additional analytic methods to unpack the learning experiences of seamless learners (or more specifically, situated learners). The artefact-oriented analysis and visualization approach reported in this paper are our preliminary attempt in making better sense of how the seamless/situated learning process may look like. Indeed, our effort can be characterized as further delineation of the local level (Hatch & Gardner 1993) of distributed cognition by foregrounding the artefacts pertinent to the stated level.

We are not the first who applied such an artefact-oriented approach in analysing learning environments, i.e. to map relevant elements in such environments into mediating artefacts for subsequent analysis or to inform future pedagogical designs. Apart from the above-stated analysis on young learners' narrative co-construction activities (Alcock 2005), which bears the greatest resemblance with our work, there had been other studies (Leadbetter 2004; Conole 2008; Lei 2008; Dimitriadis *et al.* 2009) that adopted similar analytical approaches.

The uniqueness of our work is twofold. First, we developed a visualization approach to reveal the interdependence among the mediating and outcome artefacts within relatively complex learning processes perhaps with multiple branching – as the flexibility of multiple learning pathways (see Looi *et al.* 2009) is a

significant feature for typical seamless or authentic learning environments. In our diagrams, we observed what Stahl (2002) conceptualizes as '. . . the construction of knowledge artefacts, involving physical and symbolic artefacts as starting point, as medium and as product' (p. 67). Artefacts change their roles through learners' appropriation for carrying out different learning tasks. Seamless learners ought to gradually assume greater agency in deciding what and how to learn, either individually or collaboratively and across different learning spaces, rather than always being 'dictated' by the externally imposed (e.g. purposefully designed by teachers) mediating artefacts with almost pre-defined roles to play. In turn, their habit of mind and their skills of identifying and appropriating artefacts (including their personal experiences, previously learnt knowledge and skills and previously created artefacts) to mediate both their planned and incidental learning would become crucial for them.

Second, the above-stated literature almost only portrayed ideal situations where all mediating artefacts worked well in supporting student learning. As artefacts, in nature, both enable and constrain human activities (Paavola & Hakkarainen 2004), we identified some weak links (constraining mediations) of the learning processes through our analysis on the empirical data – artefacts that may instead constrain or distract the learning tasks under certain circumstances. We believe that such findings (together with the identified positive emergent strategies and teacher's scaffolds) could be used to inform future pedagogical and even technological (re)design to eliminate or reduce such constrains (or even turn/appropriate them into good use) and strengthen the use of emergent positive artefacts.

Conclusion and future work

Humans are intrinsic sense makers (Schank 1999) or interpreting subjects (Stahl 2005), not to merely react to stimuli but looking to organize new information that they encounter so as to find meanings, significance or patterns in it. This paper reports on our effort in analysing the small-group f2f artefact co-creation processes in the 'Move, Idioms!' learning experience. We derived an artefact-oriented visualization approach, inspired by the notions of 'mediation by artefacts' and distributed cognition, to meet this end. We believe such an approach

has the potential to be applied to analyse the students' personal, out-of-school learning experiences, especially that the small-group artefact co-creation activities were designed in the way as a preparation of the students' personal artefact creation activities in informal settings. In a more general sense (i.e. looking beyond seamless learning but any type of learning activities), our analysis may inspire learning designers and teachers to seek for alternatives to designing highly scripted learning activities with prescribed sets of learning resources provided to the students, so as to achieve relatively consistent learning experiences with fixed ways of using the learning resources. Instead, one may strive for nurturing students' abilities to autonomously identify and appropriate learning resources as their mediating artefacts in their endeavours of individual and social meaning making. Still, more work need to be done to formalize the approach, to study the similarities and differences in applying the approach to analyse collaborative and personal learning experiences and how it can be applied to inform future learning experience design.

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