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Risky business or sharing the load? – Social flow in collaborative mobile learning

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ABSTRACT

Mobile learning has been built upon the premise that we can transform traditional classroom or computer-based learning activities into a more ubiquitous and connected form of learning. Tentative outcomes from this assertion have been witnessed in many collaborative learning activities, but few analytic observations on what triggers this collaboration have so far been made. However Social Flow, a concept framework that extends Csikszentmihalyi's flow theory, may help us to partially explain the triggering mechanism of collaborative mobile learning. Our case study in this article, where learners together explore a built environment as part of a simulated security guard training programme, describes how the concept of social flow in a collaborative learning space might sketch out what triggers an optimal learning experience in collaboration and what can be additionally achieved in a collaborative learning experience. In this learning context, collaborative mobile learning might be seen to prompt more knowledge generation and extra learning tasks by fostering greater motivation than other learning environments.

1. Introduction

Meet the Challenge – Make the Change (British Labour Party slogan, 1989)

The ubiquity of mobile devices is having a profound effect on our lives. We increasingly expect to be able to work, learn and play whenever and wherever we want to, and even this contemporary snapshot of mobile technology is only a step on the way to ever more opportunities that will continue to unfold. To some, the increasingly functional consumer devices that incessantly come to market provide endlessly new opportunities for applying technology to learning. Of course, at this stage, we do not know the true extent of the impact of innovative mobile devices on teaching and learning, but it is certainly true that the implications for learning are continuing to evolve.

The mobility and instant connectivity of current mobile devices enable instant information access and multiple channels for interpersonal communication anywhere at any time (e.g., KakaoTalk™ – ranked No. 1 free communication application in the Android™ market). These benefits together lead to the assumption that these devices may support 'social learning', by which learners can work and learn together within a supportive community, and build up appropriate knowledge through their active participation. By this mechanism many mobile learning researchers assert that collaborative learning with mobile supporting devices can stimulate *social learning* (Bandura, 1977; Hutchins, 1996) and *situated learning* (Lave & Wenger, 1998; Suchman, 1987). Mandryk, Inkpen, Bilezikjian, Klemmer, and Landay (2001), for instance, showed that mobile devices could create an active participation territory where instant agreement (or disagreement) could take place and provide effective coordination and negotiation among learners. Further, Facer et al. (2004) pointed out that compared to more traditional collaborative learning activities (e.g., face-to-face in the classroom), collaborative mobile learning can create higher engagement and motivation beyond the basic learning activities. Quite how this higher engagement happens beyond the '*novelty effect*' of new mobile devices or applications and how the intention to use them is kept alive in mobile collaboration is still, however, elusive.

As an analytic approach to address this question, earlier work has demonstrated that Csikszentmihalyi's *flow* theory (1990) could be of value to account for how mobile learning can achieve these qualities, by which mobile learners (compared to game-based or other traditional pedagogies) could gain unique learning experiences beyond traditional learning outcomes (Park, Parsons & Ryu, 2010). However, the study was carried out in an individual learning space, so it is not possible to directly apply its key findings (i.e., flow learning experience)

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to collaborative learning situations. The primary aim of the study reported in this article was therefore to try to examine a realistic but deliberate instant mobile collaboration against other learning settings, and explore how we might extend the analysis of Csikszentmihalyi's flow theory to embrace recent explorations of flow experience within groups engaged in shared learning activities, variously termed *social flow* (Walker, 2010) and *team flow* (Kiili, Perttula, Tuomi, Suominen and Lindstedt, 2010), which may help us to understand the benefits and the triggering mechanism of collaboration in mobile learning.

It should be noted that this article does not claim to undermine other analytic and conceptual perspectives in mobile learning, which have built upon meaningful pedagogical frameworks such as *inquiry-based learning* (e.g., Roschelle, 2003; Vahey & Crawford, 2002*), social-dialogical learning* (Jonassen & Land, 2000, Preface iv), *reflective learning* (Sharples, 2000) and *social constructivism* (Zurita & Nussbaum, 2004) to name but a few. These well-rounded frameworks also have the capability to show why mobile devices can facilitate learning *in situ*, be it in the classroom or outdoors, not simply for knowledge transmission but so that learners would interact with other learners through artefacts (i.e., mobile devices) to naturally and continuously attempt to make a process of social negotiation among participants engaged in the learning activity. Hence, Vavoula and Sharples (2002) claimed that mobile learning should be 'only' viewed in particular settings, and integrated into our daily lives, which implicitly represents a seamless flow of learning experiences.

However, these existing frameworks appear to lack dimensions that can pinpoint what triggers and sustains further collaboration, so we may need to see this type of learning activity from a new theoretical perspective. In accordance with the viewpoint above, in this research we sought to examine the following two qualitative research questions:

- How does collaboration in mobile learning affect learning outcomes?

Collaborative mobile learning assumes that, as people learn or work together, the instantaneous nature of collaboration can improve learning outcomes from a social learning perspective (e.g., Patten, Sánchez, & Tangney, 2006). This, in turn, suggests that opportunities for immediate collaboration in mobile learning would make more knowledge generation possible, and further encourage active participation in the learning activity. This has been confirmed in some ambitious mobile learning projects that leveraged collaborative learning by children when exploring outdoor natural or built environments (e.g., Facer et al., 2004; Spikol, Kurti, & Milrad, 2008), employing the knowledge that was generated earlier by themselves or by their peers. Our study is the first to analytically show whether immediate collaboration in mobile learning, where it naturally arises from context, may present an effective knowledge elicitation and maintenance process. To our knowledge there are no prior studies in which immediate collaboration is considered as a catalyst to knowledge externalisation. For several reasons, we chose to approach this research question by means of a reductionist standpoint, which might be the major limitation of this study. We presented participants with a specific learning situation with basic mobile technology (text and/or picture messaging) in this study. The participants were able to explore some physical places with their mobile devices, but they were intentionally asked to collaborate to share the knowledge that each of them had found through their own learning activity. Indeed, an anonymous reviewer of the earlier draft of this article expressed concern about this reductionist approach, asking us to present more realistic learning tasks in a more naturally reinforced collaborative situation. Though this criticism is valid, our reductionist approach might be justified by the fact that our theoretical stance is to interpret the outcomes of collaborative learning activity seemingly integrated into our daily activity with common mobile technologies, and see how collaboration might foster future learning activity. This study aimed to identify some contingent propositions along with empirical facts, without necessarily claiming causality.

- How can collaboration be triggered in mobile learning?

A more important issue that mobile learning researchers must address is what kind of collaborative learning can we conceive of within the mobile learning space. Learning is internalised within the learner's own cognition and meaning-making processes, for which the external learning context might only trigger cycles of learning motivation. A full account of collaborative learning activity thus requires a triggering mechanism that allows one to make explicit what a process achieves (i.e., the learning outcomes) as well as what triggers that process. To gain an analytic understanding of this question, three simulated learning conditions for security guard training – which might delineate a natural learning setting – were considered in this study; mobile learning with no collaboration, mobile learning with instant collaboration, and time-delayed collaboration (see Section 3 for more details.) Of course, in the three different learning configurations, it would not be possible to generalise any inherent benefits from collaboration over a very short timescale. Hence our analysis, rather than being thoroughly empirical, questions if these distinct forms of mobile learning could be examined from the perspective of Csikszentmihalyi's flow concept, in order to propose how collaboration in mobile learning might be triggered and maintained.

A note regarding our research methodology is needed again here. Unlike many scientific investigations carried out into mobile learning, we did not frame bold hypotheses in advance nor plan to test them by this study. Rather, we had simply observed what happened when people had opportunities to learn together and begun to question how collaboration in mobile learning affects their involuntary learning outcomes. From this, an analytic (rather than empirical) logic has been applied to see if social forms of flow experience could be applied to the question of what triggers collaboration in mobile learning.

2. Individual vs. collaborative learning experience

Learning has been characterised in a number of ways. For example, traditional constructivism (Glasersfeld, 1989; Wertsch, 1997) emphasises that learning is intrinsically internal meaning-making, involving the generation of new understanding and knowledge and active changes in conceptual understanding. In contrast to this solitary learning space, socio-cognitive perspectives on learning theory now place emphasis on learning as an active and social communication process (Grant, 2000, 2007; Lave & Wenger, 1991; Patten et al., 2006; Vavoula & Sharples, 2002), in which collaborative interactions are touted as a key construct of learning activities. In this way, learners are impelled to construct knowledge not only for themselves but also for one another, to collectively elaborate shared meanings (Jonassen & Land, 2000). Many mobile learning projects thus owe much to interactive outdoor learning activities (e.g., Price & Rogers, 2004), where the context can extrinsically trigger the social cognition of learning and, at the same time, develop the learner's internal cognition.

To draw upon this collaborative nature of learning, many have tried to present some conceptual theories, such as the *Learning Spaces Design Framework*' (Ryu and Parsons, 2008) or '*Activity Theory*' (Engeström, 2009). The 'Learning Spaces Design Framework' sets out three learning spaces: individual, collaborative, and situated. Within the rather different learning spaces, the framework outlines the essential factors for effective learning experience design that should be addressed by different features or functions of the relevant learning spaces. With regard to mobile learning, it argues that collaborative mobile learning is effective because learners or teachers can converse with each other, by instantly interrogating and sharing their descriptions of the learning content, as a social-dialogical process. This is often observed in traditional face-to-face learning settings, where students are working with each other, and alongside their tutors or lecturers, to grasp subject matter or elaborate their understanding of it. Ideally, in this learning process, they are developing their social, as well as intellectual, knowledge, mutually working towards a common goal and elaborating a unique intellectual and social synergy. In a more distributed setting, the communication capabilities of mobile devices can prompt collaborative learning activities. Without such communication support, collaborative learning is no longer possible and the process of participating itself is not available. In effect, the framework sees collaboration in mobile learning as triggered by the technical capability of the devices, immune to the intrinsic nature of learning activities or the internal cognitive state of the active learner. Similar to this framework, inquiry-based pedagogy emphasises that social-mediated communication technologies are needed for the affordances they can provide to learners, rather than focussing on how information can more effectively be conveyed through the mobile technologies (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2006; Rogers et al., 2005; Roschelle, 2003). However this techno-centric perspective seems not capture the critical and intrinsic qualities of collaboration in mobile learning, so a more inclusive framework is necessary to integrate both the nature of the collaborative learning activity and the internal cognition.

Engeström (2009) and novel learning theories (e.g., Jonassen & Rohrer-Murphy, 2006) based on *Activity Theory* (refer to Wertsch (1997) for more detail) partially answered this issue; collaborative learning can be triggered by tightening the social bonds that make communities knowable and liveable, emphasising the role of social relationships via mobile communication. By this, Engeström means that individuals or groups in a coherent social community could create and maintain their own collaborative learning practices, by developing collective concepts with the active help of all the participating learners. For instance, the users of Facebook™ or Twitter™, and more recently the free mobile instant messaging (IM) services (e.g., KakaoTalk™ in Korea, cited in the JoongAng Daily June 09, 2011), are quickly able to establish persistent social connections between people, and in an informal way they frequently work as a cohort of learning partners to interactively debate the opinions or knowledge of other community members. In a similar vein, Spikol et al. (2008) have seen peer-to-peer collaboration as this dialogic 'friendship' process, by which learners become shared meaning-makers among a group defined by common practices, language, use of tools, values, beliefs and so on. Various approaches have, therefore, suggested what facilitates the collaborative learning process, but it is still not obvious how this affects the individual's internal cognitive states, and how it might lead them to collaborate as a result.

In approaching this question, we assume a situation demanding high personal involvement to reach agreement, or resolving conflicts (i.e., disagreement) between peers, might be a driving force to work together. Neither the learning spaces design framework nor the frameworks grounded on activity theory can explicitly account for what would foster highly interdependent collaboration, or what internal cognitive states motivate peers to work with each other. To this end, the concept of flow in a social context has been reviewed here as a new analytical lens.

2.1. Flow experience

Prensky (2000) surmised that the best learning moments usually occur when a learner is stretched to the limit in a voluntary effort to accomplish something challenging and worthwhile, consistently generating flow experience (Csikszentmihalyi, 1990) that sustains the learner's efforts whilst they are playing game-like learning activities. It is clear that game-based learning activities can provide enjoyment, and are therefore able to maintain motivation to learn, and Csikszentmihalyi's Flow Theory (Csikszentmihalyi, 1990) has provided a contingent proposition to understand users' positive or negative experiences in their internal cognitive states.

Though it is possible to give many other definitions of flow, it is generally said that flow is a holistically controlled feeling where one acts with total involvement or engagement with a particular activity, with a narrowing of focus of attention (Nakamura & Csikszentmihalyi, 2002). That is, it means an internal mental state of absolute absorption or engagement with an activity, which we assume results in the best user (learner) experience. From a mobile learning perspective, it implies that, in order for learners to experience flow whilst engaged in a mobile learning activity, they must perceive a balance between their skills and the challenges of the activity, which should present them with playful interaction, exploratory behaviour and positive subjective experience. Only when this condition is met can an individual achieve an internal cognitive state where they have control over a challenging activity (or at least one that is not boring) and feel enjoyment and satisfaction in performing it. For instance, the Savannah project (Facer et al., 2004) allowed a high level of self-control over the learning content to construct a more pleasing cooperative learning experience in addressing the given challenges. Given that self-control of learning activities is intrinsic to all mobile learning, the relative levels of challenge and skill may either facilitate or block the motivation to learn. Csikszentmihalyi contended that optimal flow experience arises from getting the right balance between challenges and skills, as shown in Fig. 1, in order to avoid either anxiety or boredom (Csikszentmihalyi, 1990, p. 74).

Fig. 1 shows that if a learning activity is developing skills but not increasing the level of challenge (A_1 to A_2), a learner will no longer be in the optimal flow channel as his or her skills are higher than the level of difficulty of the learning activity. If the challenge increases without an associated level of skills development (A_1 to A_3), there will be anxiety rather than optimal flow. Thus, to keep the learner in the optimal flow channel (A_1 or A_4), learning activities should be re-designed in such a way that the levels of knowledge and levels of difficulty are counterbalanced. An important note of flow experience here is that human beings cannot constantly get pleasure from doing the same activity for a long time, therefore, changes to the optimal flow channel (e.g., A_1 to A_4) are inevitable. In that case, the optimal flow experience can only be achieved when the challenges given by new learning activities are dynamically synchronised with the learners' skill sets, leading to the growth and discovery of new knowledge (Csikszentmihalyi, 1990) or repeating less difficult activities by positive or negative feedback (*a.k.a.* behaviourism). This proposition might be equally applied to collaborative learning activities, where more opportunities for discovery of new knowledge are presented when others raise the level of challenge. If this is not the case, the collective learning activities proposed by

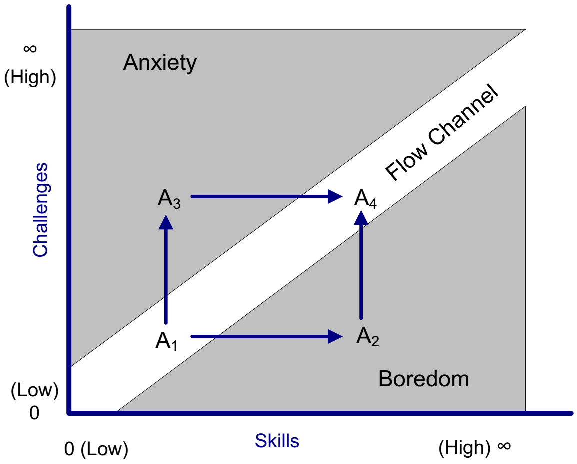

Fig. 1. Csikszentmihalyi's flow of activities.

others or peers might be simply ignored to do a less challenging or more mundane activity. Thus we need to consider the collective skill sets among the participating learners to define the optimal flow experience.

This kind of collaborative learning management, adjusting levels of joint challenges against the collective levels of skill, has been found to contribute to the development of knowledge structure and acquisition (e.g., Kozlowski et al., 2001), though a likelihood of collective flow experience has not been considered at its core. From an individual learner's perspective, at a given moment, each individual is aware of a certain number of opportunities challenging him or her, while they assess how capable they are of coping with these challenges. If the challenges of an activity are beyond the individual's skill level, demanding more than the individual can handle, they may disengage from further learning. On the other hand, if the challenges are lower than the individual's skill level, boredom may be the result, also leading to disengagement. This danger is inherent in any mobile learning context in which individual flow experience is the primary concern of the learning activity.

A simplistic way of extrapolating individual to collective flow experience might be to say the collective flow experience is equal to the total of individual flow experiences of all individuals. However, people do not necessarily associate their own interests with the group's interest, and vice versa. Therefore, the kind of social state required for this collective flow experience has to be considered, particularly for collaborative learning activities. In this paper we describe an analytic study to explore if social flow in collaborative learning activities has a meaningful effect on outcomes for individuals.

In Csikszentmihalyi's and many other studies on flow (e.g., Nakamura & Csikszentmihalyi, 2003), the core part of the optimal flow experience is generally characterised in four dimensions. These four dimensions of flow incorporate the extent to which (a) the learner perceives a sense of *control* over the learning activity, (b) the learner perceives that his or her *attention is focused* on the learning activity, (c) the learner's *curiosity* is kept aroused during the learning activity, and (d) the learner finds the learning activity *intrinsically interesting* (Csikszentmihalyi, 1990; Park et al., 2010).

To briefly explore these four dimensions further, we begin with control; flow theory can be used to examine the process of achieving learning outcomes through control over one's learning activities. For a learning activity to encourage playful, exploratory behaviours, learners should experience a feeling of control over the whole learning activity, so they will be confident to work on longer learning tasks in the face of tempting distractions. As a consequence of the feeling of control over the learning activity when in the optimal flow state, the learner's focus of attention is narrowed to a limited stimulus field (or learning content, in our case), filtering out irrelevant thoughts and perceptions or other interruptions. The person in the optimal flow experience becomes absorbed in the learning activity, and is more intensively aware of his or her own mental processes, thereby enhancing relevant mental activities such as remembering, thinking, feeling and making decisions. It is widely thought that attention is a sufficient tool for the task of improving the quality of learning performance (Webster & Martocchio, 1992). Next, learners are more motivated when the instructional design generates curiosity and interest about the learning content. Without this, people are not subject to active participation in learning. These two constructs in flow experience – cognitive curiosity and intrinsic interest – are thus considered as the initial conditions of both control and focus of attention, in order to account for how to attain competence with the learning system. They, in turn, are recursively affected by control and focus of attention, thereby stimulating active engagement in the given learning experience. An important note of cognitive curiosity and interests is that they allow self-determination or self-management of the learning activity. Indeed, learning experiences that give cognitive curiosity or interest can also give focused attention, but, in general, they do not always grow as a consequence of attentive experiences. In this regard, both cognitive curiosity and interest can be thought of as necessary conditions for learning experiences, as empirically demonstrated by Park et al. (2010). Only these two flow dimensions were thus considered in this study.

A further note on the flow dimensions employed in this study is needed here. Csikszentmihalyi considered two types of curiosity; *sensory curiosity* and *cognitive curiosity*. This article argues specifically that cognitive curiosity that engages learners in a specific topic in time-intensive learning activities is central to successful instructional design (Ryu and Parsons, 2008), by making learners aware that their knowledge structures are incomplete and inconsistent (Malone, 1981). Of course, sensory curiosity might be closely related to determining what activity would be intrinsically interesting to learners. However, they would eventually be more sensitive to the learning content and context. An important assumption of this article is that collaboration might further strengthen each individual's cognitive curiosity (rather than sensory curiosity) and interests beyond what he or she would otherwise have in their own individual learning practices.

Prior research suggests that optimal flow experience in learning activities may lead to higher quality individual learning outcomes, encouraging each learner to be more adaptable to changing environments or new learning content, and constructing creative solutions to problems with no known solutions. Previous work has used flow theory in explaining higher motivation (i.e., situational goal generation) in solitary mobile learning, and demonstrated that flow experience would be a springboard to extend individual learning experience (e.g., Park et al., 2010). However, this work did not further articulate flow theory to encompass collaborative learning experience, which is central to this study.

2.2. Raising challenge levels through collaboration: social flow

It is becoming ever more popular to talk about how we play computer games socially. Games such as Rock Band™ and Little Big Planet™ are designed for groups of friends to play or work on together. And even casual online games like Farmville™ are using the desire to play with friends to increase their user base. These are deemed as successful social gaming environments, and also enable players to participate in embedded learning tasks, such as developing skills in music rhythm and pitch awareness (in the case of Rock Band™ and its competitors).

The reason why we play or work on together seems to appeal to some intrinsic aspects of human nature, that if we are playing (or learning) with others, then we may contributing to someone else's happiness, which historical social scientists and philosophers (e.g., Aristotle and Bentham) have also claimed as a human aspiration. This implies being in the company of other people can make a great difference to the quality of a learning experience. Equally, we also value privacy and often wish to learn something alone. It is typical, however, for people in this situation to feel a lack of extrinsic challenge. Learners with traditional e-learning systems can feel a nearly intolerable sense of emptiness when they study alone, especially when they are unable to decide what to do next (Bates, 2005). This problem raises the question of how we can extrinsically motivate learners to desire to learn further, and what role working with others might play. Csikszentmihalyi (1990, chap. 8) maintained that the flow experience in either 'being alone' (solitary activity) or 'being with others' (collaborative activity) might differ. The reason that Csikszentmihalyi differentiated these types of flow experience is to reflect that we need external goals, external stimulation and external feedback to keep our attention and interests directed to a particular learning activity. In some situations, of course, being alone can help us to accomplish learning goals that cannot be reached in the company of others (e.g., preparing for final exams), in which case instead of feeling lonely, a person will enjoy solitude and might be able to learn new skills in the process. On the other hand, if solitude is seen as something to be avoided rather than a challenge, the person will resort to distractions that cannot lead to higher levels of engagement. Here, what we think of as critical to motivating collaboration is appropriate risk-taking by someone else in a group (as an external stimulation), helping the individual to update their own learning goals in conjunction with the group's goals.

Of course, collaborative learning is not a panacea. Its benefits can only be achieved at extra cost to the individual, such as requiring more effort and time to complete a collaborative activity within a group. In collaborative activities '*social loafing*', which is the phenomenon of people making less effort to achieve a common goal when they work in a group than when they work alone, is not uncommon (Jackson & Harkins, 1985). Because of the collective costs involved in collaboration, people may rationally choose "not to learn" together. It is certainly true that any collaborative learning activity requires a reorienting of attention, a repositioning of goals. When people begin to learn together, they must accept certain constraints that each person alone did not have. To some extent they will have to respond similarly to the challenges they encounter, or the relationship may come apart. Their relationship must be both differentiated and integrated (Csikszentmihalyi, 1990). *Differentiation* means that each person is encouraged to develop his or her unique learning paths, maximise his or her skills, and set their own goals. *Integration*, in contrast, guarantees that what happens to one person will affect all the others. In particular, this integration in collaborative learning activities would be legitimatised only by communication between learners (e.g., to make a shared meaning). In that case, it is simply a matter of keeping open channels of communication, where mobile learning provides an intrinsic advantage. Otherwise, conflicts between individuals are inevitable, simply because each individual learner has his or her own goals that are to a certain extent divergent from those of all other learning partners. Through this negotiation process of collaborative learning goals, they are able to find a new set of activities that will continue to keep them involved together.

An important note is needed here. In most cases, the obvious challenges they find together will be exhausted over time. Perhaps, the only way to restore flow to the integration relationship is by finding new challenges through risk-taking (as in Csikszentmihalyi's example of team sports). In solitary learning activities, there is less impetus to replace the old challenge with a new one. The learner can thus simply choose not to learn at no cost, maintaining the status quo. By comparison, collaborative learning activities would have a greater chance of developing a new challenge depending on the partners' level of skill, and in turn, more complex challenges are able to be tackled. With this in mind, learning designers often try to implement 'sociability by design', in other words, to structure learning activities so that learners will have numerous opportunities to simply 'hang out' with each other and thus form interesting relationships to work together, resulting in rather unexpected learning outcomes. Collaborative learning with mobile devices may equally be designed to foster an integrated flow learning experience.

In the same vein, many game researchers have already asserted the merits of social gaming whereby players will join with others to tackle more challenging tasks. The relative levels of challenge and skill that the group will face together might be key to seeing the distinctive nature of the social form of experience. This implies that one of the most important elements of these social experiences might be shared social interaction where people can go above and beyond their own normal range of ability.

Recent biological evidence (e.g., Cohen, Ejsmond-Frey, Knight and Dunbar, 2009) also supports this contention, suggesting that team-play encourages individuals to take on more risks and challenges (i.e., higher risk-taking social attitudes) than when working alone. The benefits of mobile learning can be also seen from this team-play learning perspective. People in collaboration would have more opportunities to learn something in this social flow from the challenges taken on by their peers (of course, from time to time, they reciprocally create new challenges in response to the challenges presented by their peers). Hence, at a given moment, they can assess how they are capable of coping with these challenges 'together', lifting or lowering the overall levels of challenge. Quite possibly, learning alone would have minimised the taking of further challenges, but when people work together, they are readily able to raise the levels of challenge to undertake further learning activities. Interestingly, this runs counter to Csikszentmihalyi's (1990) claim that the 'natural' or 'unlearned' pursuit of self-interest contributes to the greatest happiness, which might indicate a need for a new concept beyond the individual flow experience.

As to the concept of social flow, Walker (2010) addresses what happens when a group of people are absorbed together in a challenging physical activity. In his first study, the participants thought more collaborative physical activities (e.g., playing football or walking in groups) were associated with more enjoyment than solitary physical activities (e.g., playing golf alone). The following two experimental studies further articulated the concept of social flow, revealing that the collaborative physical activity was rated as being more enjoyable and provoked emotions usually associated with individual flow experience, including feeling alive, focused and cheerful. Crucially, those participants who had found their respective tasks more challenging and requiring of further skill felt more flow experience than those who did not.

Turning to the mobile learning activity, this implies that people collaborating together can voluntarily raise the levels of the challenge of a learning task whilst performing it. In particular, the instant communication channels of mobile devices could help them to promptly share challenges within activities to keep them working together. This triggering mechanism, as illustrated in Fig. 2, would explain how collaboration could maintain their motivation, strengthening their social flow by this cyclic process (i.e., collaboration and social flow is co-evolved to cope with on-going challenges raised by each individual). The research objective of this article is to see if this kind of social flow can be observed in a collaborative learning activity, and in turn, if mobile learning can further extend this social form of flow experience.

3. Experiencing social flow with collaboration: a case study

Section 2 made a solid case for how collaboration in mobile learning might take place and be maintained through social flow. To empirically substantiate this claim one would ideally want to observe its triggering and developing mechanism in real mobile learning situations. There are relatively few articles in the mobile learning literature where real learning activities are administered to different learning situations (i.e., individual and collaborative mobile learning), thanks to the intrinsically different learning paths, for the purpose of comparison.

As an approximation to this ideal we present here a study in which a small number of learners were taught different versions of mobile-mediated learning and then their behavioural outcomes were collected. It is difficult to generalise from a single evaluation using this method, and this approximation differs from a real mobile learning context in certain critical aspects; however, the exercise does provide some empirical support by demonstrating that social flow could take place and produces a useful analytic tool to develop collaborative mobile learning. Comparison of the differences identified in three different learning configurations also draws attention to potential strengths and weaknesses in the social flow approach. The main purpose of this study was thus to explore whether collaboration via mobile devices could be associated with unique aspects of learning experience, and what different learning outcomes might result from collective flow experience.

To implement our study, a simulated but realistically situated learning programme was developed in the domain of security guard training. This domain has a number of advantages from an experimental perspective; it has clear learning goals, these learning goals can be both explanatory and exploratory, it can be explored realistically in a large university campus, domain experts are readily available for consultation, and it is an easily understood domain for non-expert participants. The programme was set up to allow the participants to separately patrol several physical locations in pairs, to find as many security issues as they could, and collaboratively learn from each other.

Three types of learning configurations – '*solitary mobile learning*', '*instant collaborative mobile learning*' and '*time-delayed collaborative learning*' – were deployed to assess the differences in both learning outcomes and flow experiences rated by the participants (i.e., individual flow experience for solitary mobile learning, and the other two settings for social flow experience). All three learning settings allowed the 'trainee guards' to participate in a security patrol mission using a mobile device, encouraging them to act both on their own and collaboratively, and construct their own knowledge of the patrol mission, as well as sharing knowledge with other 'trainee guards', if necessary. Six patrol locations were specified at various points across the university campus, and each patrol location had instructions for the trainees to learn (Fig. 3).

The same six locations were used throughout this study. Each subject in the two collaborative conditions (i.e., instant collaboration and time-delayed collaboration) only visited three areas personally, to deliberately emulate a collaborative learning context. This experimental setting thus required each pair to learn about the six locations together. The participants in the solitary learning condition were asked to complete the six patrol tasks alone, as a control condition. The information about the security issues related to the places was given by the instructions on mobile devices, as shown in Fig. 3; however not all the security concerns of the sites were presented. This manipulation was intentional to see if our participants would meet the challenge to find extra security issues together.

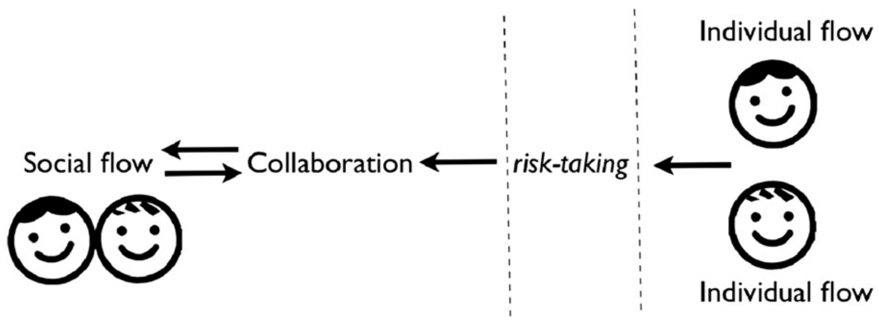

Fig. 2. Social flow may make explicit why learners would cooperate and how it can be strengthened by collaboration. Risk-taking works as a necessary condition for social flow beyond individual flow experiences.

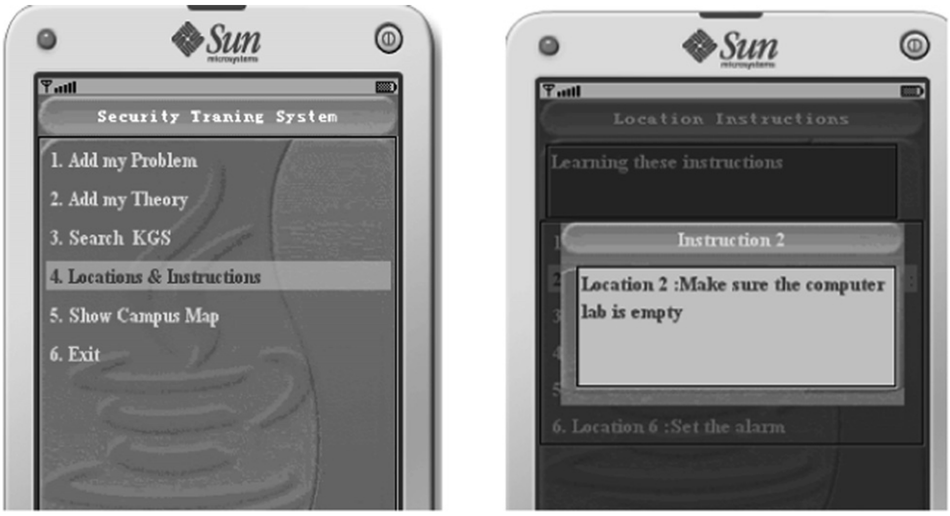

Fig. 3. The mobile learning system guided trainees to locations where they were given instructions. The instructions had some information to be learnt. However, not all the knowledge for the security training programme was included in the instructions, so some participants were able to build their own knowledge that was not specified in the instructions.

3.1. Participants

Forty-five subjects volunteered, none of whom had physically explored the premises in a security role before. They had a similar educational background (college graduates), and were aged between 20 and 28. Only five subjects were assigned to the solitary learning system, which is the control condition. The rest were distributed at random to one of the two collaborative settings (i.e., ten pairs to instant mobile collaboration, and the other ten pairs for time-delayed collaboration.)

3.2. Design

This study mimicked a between-subjects experimental design. The three types of learning configurations acted as the between-subjects independent variable, while several types of learning outcomes were collected; the ratings on statements regarding flow experience (see section 3.3 for details of these statements), learning performance measured by how well each participant had learnt the security issues from both their visits and their partner's visits, types of knowledge generated (problem, theory, agreement-disagreement or suggestion), the number of security issues they found and the level of knowledge described in their self-report.

3.3. Apparatus

Each participant was equipped with a mobile device (Nokia E71™ or E66™ with 3G network connections) installed with the "Online Patrol Training System (OPTS)" as depicted in Figs. 3, 4 and 5. The difference between the two collaborative configurations was that the

Fig. 4. Text/Picture based collaborative communication.

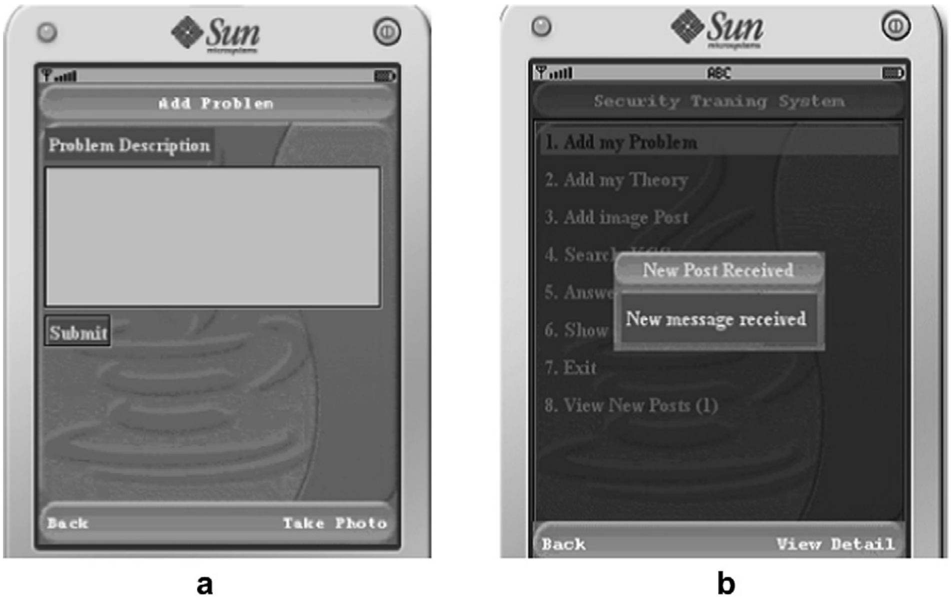

Fig. 5. Working together each other. (a) Adding up new information; (b) As soon as new information is added, the partner is automatically sent the notification.

instant mobile collaboration supported instant exchange of text and photo messages between the trainees (Fig. 4). On the other hand, the time-delayed collaboration only allowed the uploading of photos to a server for later face-to-face collaboration.

In the instant mobile collaboration, as soon as new text or photos were added (Fig. 5a), the partner was automatically notified (Fig. 5b). In contrast, the time-delayed collaboration did not allow this instant communication. We believe that comparing these forms of collaboration can reveal what is lacking in this time-delayed collaborative learning experience, in terms of social forms of flow and learning outcomes.

To examine if the subjects had achieved certain learning outcomes after the experiment, a retention test was administered the following day, with six multiple-choice questions related to the security issues of the six patrol locations. An important note is needed here. As described previously, each participant in a collaborative learning setting had physically visited only half of the six locations, so they had to answer questions about security issues with regard to the places they had not visited based only on their collaboration during the patrol (instant mobile collaboration) or the wrap-up session (time-delayed collaboration). Due largely to this manipulation, the retention test (i.e., if they could answer half of the questions from their own learning, and the other from someone else) was expected to show the effects of instant mobile collaboration, if any.

The six statements relating to flow experience were then rated on a five-point Likert scale. These were adopted from a previous study (Park et al., 2010), which suggested the benefits of mobile learning can be seen by the optimal flow experience aroused by the two necessary conditions – ‘cognitive curiosity’ and ‘intrinsic interest’ – rather than control and focused attention. The additional seventh statement was

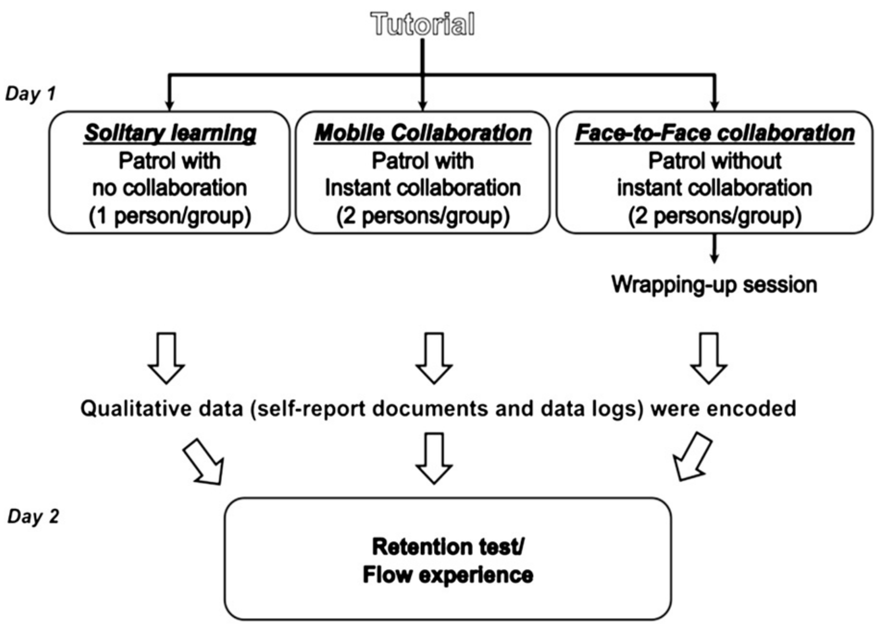

Fig. 6. Experimental procedures. Note that time-delayed collaboration has a wrap-up session just after the patrols.

Table 1
Scaffolding words used in the experiment.

[Problem] Person A	There are not enough security cameras at student car park A.
[Theory] Person B	Car park A is frequently patrolled, so it is relatively safe.
[Disagreement] Person A	I disagree. As the car park is completely open, it is hard to secure the entire area.
[Agreement] Person B	I agree with Person A.
[Suggestion] Person B	The student car park needs more security cameras to cover the entire area.

inserted to see if working in a group had encouraged them to tackle more challenging tasks, over and above those specified, as a result of being further motivated. If this was the case, we would be able to see collaboration as a key benefit and perhaps influence some aspects of mobile learning curriculum development. Note that different terms (in parentheses below) were used to evaluate the solitary mobile learning system.

- Q1 (Cognitive Curiosity): Working together with my partner excited my curiosity (Working with the system excited my curiosity*);
- Q2 (Cognitive Curiosity): Interacting with my partner made me curious (Interacting with the system made me curious*);
- Q3 (Cognitive Curiosity): Working together with my partner aroused my imagination (Working with the system aroused my imagination*);
- Q4 (Intrinsic Interest): Working together with my partner bored me (Working with the system bored me*);
- Q5 (Intrinsic Interest): Working together with my partner was intrinsically interesting (Working with the system was intrinsically interesting*);
- Q6 (Intrinsic Interest): The whole learning session working with my partner was fun (The whole learning session working with the system was fun*);
- Q7 (Risk-taking): Working with my partner allowed me to look into other issues other than the patrol instructions given (Working with the system allowed me to look into extra issues other than the patrol instructions given*).

* *Statements for the solitary mobile learning system.*

3.4. Procedure

Fig. 6 shows the procedures for each learning condition. All the participants firstly attended a tutorial session that gave them the necessary information to carry out their patrol task on campus, including general security issues of the campus, the six locations to be patrolled and how to use the "Online Patrol Training System (OPTS)" (see Figs. 3–5). In the main experimental session, they were told to only visit the locations guided by the OPTS, find as many security issues related to their visits as they could, and, if required, to take photos of the site and describe the issues when submitting them to the database. Each location has two or three security issues, which were identified for us by two security professionals. The instructions in the OPTS included some security issues they had to attend to, but did not completely cover all the security issues identified by the security professionals. This was deliberately organised in order to see if our participants could find these security issues (i.e., those are not mentioned in the instructions), not to limit our participants only to the instructions about what they had to learn.

To ensure the quality of the descriptions of the issues (i.e., what they had found as security concerns), they were encouraged to think creatively and act collaboratively during the patrol, externalising their knowledge by proposing their problems and/or theories. For instance, when a participant describes an issue such as 'the traffic barrier at Gate 3 is visually too weak', then he or she takes photos of the barrier and submits the knowledge together with the photos to the database. However, this free style description would make the analysis of eliciting knowledge quite onerous. Hence, they were asked to use some '*scaffolding*' words used in the experimental system; '*problem*', '*theory*', '*agreement/disagreement*' and '*suggestion*' (the statement above would be coded as a 'problem'), as shown Fig. 5b. Table 1 shows an example of two subjects contributing their opinions by using the scaffolding words.

However, it should be noted that collaboration during the patrol was not allowed for those who used the time-delayed collaboration condition, so that it seems quite obvious that they would not show the same level of knowledge description as expected in the instant collaboration condition. This lack of instant knowledge elicitation was compensated for by the wrap-up session just after the patrol task. Thanks to this temporal difference between the instant collaboration and the time-delayed collaboration, it was hoped that we could see some behavioural differences related to whether or not the collective skill set in the pair improved through taking further challenges.

Again, since the subjects in the time-delayed collaboration were unable to collaborate during their patrols, as soon as they finished their patrol they attended a wrap-up session with their partner. In this meeting they were asked to externalise their knowledge or learn from each other, and a desktop computer (with a large monitor) was used to facilitate this collaboration process so they could show their uploaded

Table 2
Learning performance (Mean/s.d, max: 100).

System	*N*	Visited	Un-visited
Mobile solitary	5	91.90 (16.44)	–[a]
Instant mobile collaboration	10[b]	89.85 (19.27)	84.70 (17.35)
Time-delayed collaboration	10[b]	81.40 (23.11)	71.25 (22.54)
Sig.		n.s	$p \leq .05$

[a] Mobile Solitary asked the participants to visit all the six locations.
[b] 10 pairs = 20 subjects.

Table 3
Mean frequency of each coding category (mean/s.d).

	Problem	Theory	Agreement (disagreement)	Suggestion
Instant mobile collaboration	4.20 (1.94)	5.65 (2.28)	1.13 (1.02)	3.30 (1.59)
Time-delayed collaboration	3.95 (2.30)	5.05 (2.21)	2.50 (1.49)	4.20 (1.64)
Sig.	n.s	n.s	$p \leq .01$	n.s

photos to each other. The subjects were then asked to use the same scaffolding words (i.e., problem, theory, agreement-disagreement, suggestion) to pool their knowledge and write a joint report. All the experimental sessions were conducted pair by pair, and each pair completed the whole experiment in about 1 h.

4. Results

Table 2 shows the learning performance outcomes for each of the three configurations. These results indicate that participants in the time-delayed collaboration condition seemed to perform the experimental task less well than the other two experimental groups. This might indicate limitations to this type of instructional design in this training program context, where collaboration is delayed. Note that the time-delayed collaboration did not allow the participants to physically visit all of the six places, nor have instant communication. Importantly, this seems to indicate that instant collaboration through mobile devices has a certain effect against the time-delayed face-to-face collaboration, regarding learning about the un-visited places. Note that both collaborative systems asked the participants to visit half of the six places, which positioned collaboration (either instant or delayed face-to-face collaboration) at the centre of the learning affordances of the two systems, against the solitary learning where there was no collaboration at all.

A *T*-test was conducted on the learning performance regarding the places that were not personally visited, revealing that there was a significant effect of the given system ($t_{38} = 2.12$, $p \leq .05$). This can be interpreted as showing that the participants working together with mobile learning effectively learnt by instantly sharing the knowledge generated by others. However, the participants in the time-delayed face-to-face collaboration had to wait till the wrap-up meeting, and then learnt from each other, which could be less motivating than instant mobile collaboration. The data can be carefully taken to suggest that, at the very least, the benefit of instant collaboration is evident, a factor not present in the time-delayed collaborative learning.

As another learning outcome, for mobile collaboration, participants' communication logs were recorded. For the time-delayed collaboration, the subjects met face-to-face just after they had completed their patrols, and their conversations in the wrap-up meeting were also documented and encoded. To explicitly see how the participants generated their knowledge, we analysed the encoded data by using the *verbal protocol analysis* method (Gilhooly & Green, 1996). After encoding the raw transcripts into segmented sentences, they were further matched into the five pre-defined coding categories, with the scaffolding words, i.e., problem, theory, agreement (disagreement), and suggestion (see Table 1 for further explanation).

Table 3 summarises the data collected, together with the mean communication events for the two collaborative systems. Note that the solitary learning system had no collaboration, so it is not analysed here. Overall, the two collaborative systems did not exhibit much difference, except for agreement (disagreement) being significantly higher for the time-delayed collaboration group. A *T*-test confirmed this ($t_{38} = -3.97$, $p \leq .01$). A possible explanation may be that the participants in the instant mobile collaboration could frequently check and interrogate their knowledge on the spot; on the other hand, the participants in the time-delayed collaboration needed a heavy negotiation process to build up a consensus with their incomplete recall in the wrap-up session.

This interpretation was partially supported by inspecting the types of knowledge generated, as shown in Table 4. We analysed this, separating out 'knowledge by collaboration' and 'knowledge without collaboration'. The former refers to the information in the generated transcripts, which was created from the pair's collaborative effort, and the latter being generated individually, without conversing or consulting with a partner. Since the participants used the scaffolding words to build up the transcripts, any context-related information in the 'Q&A' structure has been counted as 'knowledge by collaboration.' Looking at Table 4, it appears that the instant mobile collaborative learning system generated more knowledge from collaboration, and this was assessed by a Chi-square test ($\chi^2 = 14.18$, $p \leq .01$).

Contrary to the three learning outcomes above, the ratings of flow experience revealed a striking difference, which might suggest the distinctive nature of mobile learning, and possibly the implications of social forms of flow experience. 'Cognitive curiosity' and the desire to attain competence with the learning application may motivate learners to develop more skills or further examine the learning space, so higher ratings on these statements imply a willingness to exploit the learning activity further. 'Intrinsic interest' can be deemed as subjective experiences during interactions that are characterised by perceptions of pleasure and involvement. Higher ratings on these statements mean the learners are so intensively involved in the learning activity that putting additional time and cognitive effort into the learning activity is done willingly. Finally, 'risk-taking' behaviour is associated with these two contributors, in that it can generate a further motivation to learn. This is more likely to lead the group to find new sources of knowledge through collaboration, outweighing the possible costs of collaboration such as the additional time and cognitive effort required. Hence, it can be seen that higher risk-taking behaviour by individuals may have benefited the group as a whole, because the group would reap the rewards of the higher risk taker's discoveries. A further note on this statement is needed here. As discussed above, being in the company of others in learning may make a difference to the

Table 4
Mean frequency of each coding category.

System	Knowledge by collaboration	Knowledge without collaboration
Instant mobile collaboration	122	145
Time-delayed collaboration	72	172

Table 5
Mean ratings of flow experience (mean/s.d).

System	Cognitive curiosity	Intrinsic interest	Risk-taking
Mobile solitary	2.52 (0.83)	2.71 (0.92)	1.35 (0.77)
Instant mobile collaboration	3.80 (0.77)	3.88 (0.75)	3.95 (0.89)
Time-delayed collaboration	3.20 (0.95)	3.00 (1.08)	3.25 (0.79)

Responses from each contributor except risk-taking were averaged out to give one value in each column.

Table 6
Mean frequency of security issue found (mean/s.d).

System	Mobile solitary	Instant mobile collaboration	Time-delayed collaboration
Number of security issues found in total	9.32 (3.24)	14.72 (6.34)	10.48 (4.16)

Table 7
Mean ratings of flow experience.

System	Cognitive curiosity		Intrinsic interest		Risk-taking	
	Close friend	Never met	Close friend	Never met	Close friend	Never met
Instant	4.50	4.00	5.00	4.00	4.50	4.50
Time-delayed	3.50	4.00	4.00	4.50	3.00	3.00

quality of a learning experience. The learner in that situation might feel the richness of extrinsic challenge presented by the others. Here, as critical to motivating collaboration, appropriate risk-taking by someone else in the group might be observed. By this we mean that those who had a more collaborative learning experience would be emboldened to identify more security issues than those specified in the instructions given in the experimental setting.

Table 5 gives the mean ratings for the three learning settings across the two contributors to the flow experience, and the 'risk-taking' measure relating to collaborative benefits. In all three measures the instant mobile collaboration gains the higher ratings, which indicates that our participants had somewhat different flow experiences in the instant mobile collaboration. Clearly, with only the small sample size using the solitary mobile system, statistical comparisons are inappropriate. Also, the minor differences in the learning activity between the instant mobile collaboration and the time-delayed mobile collaboration might be an issue not amenable to further statistical analysis. Nonetheless, at the very least, the values in Table 5 demonstrate that the instant mobile collaboration might be legitimatised for better forms of flow experience beyond individual flow experience (mean 3.80 vs. 2.52 for cognitive curiosity; 3.88 vs. 2.71 for intrinsic interest), and the higher risk-taking attitude inspired by the instant mobile collaboration (mean 3.95 vs. 3.25 vs. 1.35 for risk-taking) may be proposed as a factor to help explain the differences between the three learning systems.

In terms of social flow, this higher risk-taking attitude was predicted to develop new challenges depending on the partners' level of skill set, and in turn, more complex challenges could be tackled. In this respect, it is interesting to see if the instant collaboration group had found extra security issues or tasks that were not specified in the instructions. According to the security professionals consulted, a total of 16 security issues at the six sites were identified. Table 6 shows the mean frequency of the security issues found by our participants. Again, this is not amenable to further statistical analysis, partly because of the small sample size of the solitary learning situation, and mostly because of the lack of instant interrogation in the time-delayed collaboration condition. Also, two pairs in the instant mobile collaboration produced some extra issues not mentioned by the security professionals. Notwithstanding this limitation, it can be seen that being in the company of others in learning may make a positive difference to the quality of a learning experience (i.e., the number of security issues found – mean 14.72 vs. 9.32 (mobile solitary) vs. 10.48 (time-delayed collaboration)).

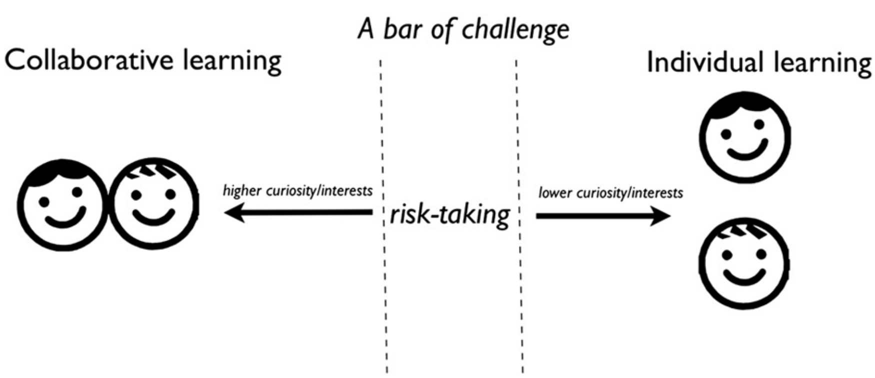

Fig. 7. Social flow that raises the bar of challenge.

5. Conclusions

The educational benefits of learning with others may be difficult to assess, given the complexities of distributed cognition (Hutchins, 1996), but are nevertheless widely acknowledged. In this study, when considering the impact collaboration has on a mobile learning activity, our case study showed that when potential learners had manageable challenges, and they together could see them as positive self-improvement opportunities, then an intention to collaborate seemed to be triggered. This social form of learning experience deserves to be considered in collaborative learning situations, and implies that the development of knowledge in collaboration (refer to Table 4) can be attributed to dynamic interaction with other learners.

In our instant mobile collaboration scenario, we observed that hardly a learning activity went by without further examination or consultation with the other active partner, even though this demanded collaborative effort such as more time and cognitive load to complete the learning task. This was not the case in either the solitary learning environment or time-delayed collaboration, where the participants might simply choose to "not learn" at the scene of a learning event and maintain the status quo by taking lesser challenges. In this light, this study suggested that the benefits of collaboration within a social flow experience overcame any costs involved in the collaboration activity, and this might be a novel framework to account for the benefit of collaboration.

Indeed, as depicted in Fig. 2, we posited that social flow might account for collaborative learning outcomes and its triggering mechanism, but we did not actually form this hypothesis for the subsequent case study. Instead, we simply hoped to observe that potential collaborators in our case study were more likely to be motivated to learn together based on their shared situational goal making. Comparison of the three learning configurations allowed us to point out the potential value of the collaborative mobile learning experiences available only in this context, and how the mobile communication would foster a new set of learning activities. The evaluation of social flow experience and risk-taking behaviour confirmed the advantages of collaborative mobile learning over the other formats.

Turning to the empirical data presented, the detailed account of what the two collaborative groups did (instant mobile collaboration vs. time-delayed collaboration) provides a good case for the consideration of social flow and some insights as to why mobile learning, if well designed, might be more effective than other learning activities in some circumstances. There are of course a number of potential limitations to this study. For example, as Engeström (2009) claimed, collaborative mobile learning might be better effected for people who already have strong ties to motivate their collaboration. This factor has not been considered in this case study described thus far in this paper. In this respect, it is interesting to note that another small study with four groups was carried out. Two pairs knew their partners well prior to the experiment, whilst the other two pairs did not. They were asked to do the same tasks presented in Section 3, and each pair was assigned into one condition. We should reiterate that, because of the limited size of this study, our main claims for social bonds are analytical rather than empirical. Clearly with only one pair using each method statistical comparisons are inappropriate. However, the two collaboration settings (i.e., instant collaboration and time-delayed collaboration) were given broadly similar ratings for flow experience (Table 7). Notwithstanding its limitations, this trial does suggest that the level of social bond might not be so significant where the extrinsic learning motivation is strong. This issue needs of course to be more rigorously examined in the other experimental settings.

6. Discussion and limitations

Social flow is a concept that has only recently come to the attention of mobile learning researchers, but there is much potential in further exploration of its implications for collaborative mobile learning. Many educational practitioners have long believed that collaborative learning activities enable exchanges of thoughts, emotions, and ideas among learners (Childress & Braswell, 2006). In turn, this bonds them with others participating in the same learning activity (i.e., forms a learning community), which is likely to improve their achievement. The practical contributions of this article are to show analytically that this social flow experience can be maintained in collaborative mobile learning, and partially demonstrate that each individual's solitary flow experience may not displace the group's collective flow experience.

Based on the interpretations discussed above, Fig. 7 sketches out the concept of how social forms of flow can influence the levels of challenge learners are able to take on, whereby a learning group can jointly raise the level of challenge in performing a collaborative learning activity. Of course, further studies are still needed to confirm this. However, in the case of instant mobile collaboration, it can be seen that learners are ready to take extra challenges (or risk-taking) from others when the learning design encourages each person to develop his or her unique learning paths with the collaboration, maximise his or her skills, and set their own goals. We also observed that they seem to be well aware that their own achievements will affect all the others in the group in collaboration. We would claim that the communication capability embedded in mobile devices is thus a facilitator of this integration process.

Many collaborative learning proponents would echo this perspective, and our case study also supports this contention. In our context, mobile learning has a certain effect of uniting learners to gain the collective skill set to form a rather different flow experience. Having said that, it can be seen that collaborative partners with the same learning goal orientation can have adaptive responses to new and/or challenging situations, which was confirmed by the number of the security issues identified. In particular, individuals displaying this orientation would treat new and/or challenging situations as opportunities for self-improvement through collaboration given by the mobile learning activity, and this could be at the core of social flow in collaborative mobile learning.

The limitations of this study are obvious, given the difficulty of actually measuring the intensity of flow experience. Validating our claims is open to question unless our measures of flow experience are sound. There are other approaches to measuring experience, for example Microsoft™ does extensive game testing, measuring individual enjoyment by interrupting the user's interaction every few minutes via a dialogue box asking them for their current level of engagement. One might question, however, the accuracy of such a disruptive form of measurement. Alternatively, other recent research suggests the possibility of employing some neuro-physiological indicators such as EEG (Electroencephalography) and HRV (Heart rate variability) (Martin & Kerr, 2009), though this cannot, of course directly measure cognitive processes. We have limited our measures to rating statements about flow experience, and assumed that the sum of the individual flow experiences alone would not equate to the social flow experience of the group, which might be wrong. We also know very little about the external motivations that are associated with this case study and how each security trainee responded to the external motivations that they vicariously felt about the challenges given by others. We did not consider any learning setting to avoid this issue, which consists of another limitation of this study. Without clearer explanations on these matters, the social flow experience effect is open to further interpretation.

The results and limitations of this study raise several questions that could be addressed in future research. As one of the anonymous reviewers of the earlier draft of this article clearly indicated, the learning task itself seems a mundane activity, which may not be suitable for invoking sufficient social flow. The communication in this study was based only on text and photographic images, and it is possible that richer types of communication such as video streaming might lead to rather different learning outcomes. Studying how peers might co-develop a challenging task for their learning activity, and how they would work adaptively together on that task, would be another way forward for validating the social flow experience effect in collaboration (i.e., whether they are able to improve their collective skill set to meet the challenging task). Hence, a natural learning situation asking higher cognitive demands might be considered in the future to further exercise the concept of social flow. A third way to see the social flow would be associated with the level of social bond, which has not been extensively explored in our study. Perhaps the level of familiarity within a pair would have certain effects on their learning experience, despite our limited analysis not detecting this effect. Finally, for further validation, there is a need for adversarial research to challenge the claim that social forms of flow are more beneficial than solitary forms of flow. For instance, there is a substantial literature on group performance that suggests that groups frequently do not achieve the level summed to the competencies of individual members (*Social loafing effect*: Karau & Williams, 1993). More research on social forms of flow may reveal when groups can maximise their potential, and when they do not (Sawyer, 2007). In particular, how mobile learning can facilitate this social form of flow – as a relatively extrinsic motivation – is still elusive. We might seek to further elaborate our measures (e.g., evaluative statements for flow experience) to be more specific to social flow.

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