Raising the Bar of Challenge with Collaboration: *Social Flow* in 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 this have been made. However *Social Flow*, a concept that extends Csikszentmihalyi's flow theory, may help to explain the benefits and the triggering mechanism of collaborative mobile learning. Our empirical studies, where learners together explore a built environment as part of a simulated security guard training programme, showed that social flow in a collaborative learning space might be a key factor in providing the conditions for optimal learning experience. Further, in the experimental context, collaborative mobile learning can be seen to prompt more knowledge generation by fostering more learning motivation and ambitious behaviour (i.e., risk-taking) than other learning environments.

Keywords

Flow, Social Flow, Mobile Learning, Collaboration, Risk-taking

1. INTRODUCTION

The abundance of mobile devices is having a profound effect on the way these technologies impact on our lives. We increasingly expect to be able to work, learn and study whenever and wherever we want to, and even this current view of mobile technology is only a step on the way to ever more opportunities that will continue to unfold. The implications for informal or professional learning are also continuing to evolve, as are the notions of '*just-in-time*' learning and '*found*' learning.

The mobility and instant connectivity of current devices enable instant information access and ample interpersonal communication anywhere at any time. These benefits together lead to the assumption that learning with these devices would allow *social learning*, by which learners can work and learn together within a supportive community, and build up appropriate knowledge through active participation. By this mechanism many mobile learning researchers assert that collaborative learning would stimulate social learning and situated learning. Mandryk *et al.* (2001), for instance, showed that mobile devices could create an active participation 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, implying that people in a group might have a distinctive level of self-control over their own learning. Quite how this happens and is kept alive in mobile collaboration is still elusive, however.

As an analytic approach to address this question, the first author and his colleagues (Park *et al.*, 2010) demonstrated that Csikszentmihalyi's flow theory (1990) could account for how mobile learning can achieve these benefits, by which mobile learners (compared to game-based or other traditional pedagogies) could gain better learning outcomes. However, this study was carried out in an individual learning space, so we cannot directly apply its findings to mobile collaboration.

The primary aim of the study reported in this article was therefore to try to identify some particular outcomes from mobile collaboration, and in turn, how we might extend the analysis of flow theory to embrace the more recent concept of *social flow* (Walker, 2010), which may help us to understand the benefits and the triggering mechanism of collaborative mobile learning. It should be noted that this article does not claim that other analytic perspectives in mobile learning should be overlooked however. Instead we believe that collaboration in mobile learning may exhibit less obvious qualities in terms of these prior perspectives, and that we may see this type of learning activity from a new theoretical perspective.

Related to the viewpoint above, in this research we examine the following questions:

- *How does collaboration in mobile learning affect learning outcomes?*

Collaborative mobile learning presupposes that, as people learn or work together, the instantaneous nature of collaboration can improve learning outcomes from a social learning perspective. This, in turn, suggests that *the prompt collaboration opportunities in mobile learning would make more knowledge generation possible*. This can be seen in some ambitious projects to leverage collaborative learning by children when exploring outdoor natural or built environments (e.g., Facer et al., 2004, Spikol et al., 2008), employing the knowledge that was generated earlier by themselves or by their peers. Our study is the first to empirically demonstrate 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.

- *What would trigger collaboration in mobile learning?*

One important issue that mobile learning researchers must address is what kind of collaborative learning can we conceive of within the mobile learning space? To gain a deeper theoretical understanding of this question, three simulated learning systems for security guard training were considered (*mobile learning with no collaboration*, *mobile learning with collaboration*, and *face-to-face collaboration*; Refer to Section 3 for more details.) Of course, in this experimental setting, it would not be easy to observe any significant benefits from collaboration over the very short term. Hence we discuss if these distinct forms of learning activities could resort to Csikszentmihalyi's flow concept to conceive a formative stance for collaborative mobile learning.

A note regarding our research methodology is needed here. We did not frame bold hypotheses in advance or plan to test by empirical study. Rather, we had observed what happened when people had opportunities to learn together and begun to question how collaboration in mobile learning affects learning outcomes. From this, an inductive logic came into play to see if the concept of social flow could be applied to the question of what factors might trigger collaboration in mobile learning.

2. WHAT TRIGGERS COLLABORATION

Learning has been characterised in a number of ways. For example, *traditional constructivism* emphasises that learning is intrinsically internal and personal, involving the generation of new understanding and knowledge and active changes in conceptual understanding. Next to this solitary learning space, *socio-cognitive perspectives* on learning theory now place emphasis on learning as an active and social participation process, in which possibly collaborative interactions are viewed as a key construct of the content of learning activities (Lave and Wenger, 1991). That being said, many mobile learning projects owe much to outdoor learning activities (e.g., Rogers et al., 2002), where the context can intrinsically trigger the collaborative nature of learning.

To draw upon this collaborative nature of learning, many have tried to present some conceptual theories, such as *Learning Spaces Design Framework* (Ryu and Parsons, 2008), *Activity Theory* (Engeström, 2009) or *Flow Theory* (Csikszentmihalyi, 1990). The *Learning Spaces Design Framework* sets out three learning spaces: individual, collaborative, and situated. Within these different learning spaces, the framework outlines the essential factors for effective mobile learning experience design that should be addressed by different features or functions of the relevant learning spaces. In particular, it argues that collaborative learning could be even more effective when learners can converse with each other, by interrogating and sharing their descriptions of the learning content. Here, the capabilities of mobile devices uniquely contribute to foster collaborative learning activities, and in turn, this learning is no longer static subject matter but the process of participating itself. In effect, collaboration is triggered by the technical capability of the devices rather than the intrinsic nature of learning activities. However this techno-centric perspective seems to be unlikely to capture the critical qualities of collaboration, so a more inclusive framework becomes necessary.

Engeström (2009) partially answered this issue; collaborative learning could be triggered by tightening the social bonds that make communities knowable and liveable, emphasising the role of mobile communication. By this he 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. In a similar vein, Spikol *et al.* (2008) have seen peer-to-peer collaboration as this 'friendship' process, by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs and so on. Both frameworks can reason about what makes the collaborative learning process explicit, but quite how the social bonds trigger collaboration is still open to question.

In approaching this question, we may assume that sustaining high personal involvement to reach agreement, or resolving conflicts (i.e., disagreement) between peers, might be compelling areas to examine. Neither the learning spaces design framework nor the frameworks grounded on activity theory can explain what would trigger highly interdependent collaboration, or what motivates peers to collaborate with each other. To this end, the concept of flow in a social context can be viewed 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 to achieve something. He saw that game-based learning would be of great value from this perspective, and indeed it is clear that game-based learning activities can be more joyful and fun, at the very least, and are thus able to keep alive motivation to learn. As such, Csikszentmihalyi's Flow Theory (*ibid.*) has, to a larger extent, provided an analytic foundation to decipher users' positive or negative experiences in many Human-Computer Interaction (HCI) research arenas.

Though there are many different 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 (Csikszentmihalyi, 1990). 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. For instance, both the Savannah project (Facer et al., 2004) and the Ambient Wood project (Rogers et al., 2002) allowed a high level of self-control over the learning content to construct a more pleasing learning experience. Given that self-control is intrinsic to mobile learning, the relative levels of challenge and skill may either facilitate or block the motivation to learn. This learning manipulation through the levels of challenge has been found to contribute to the development of knowledge structure and acquisition (Kozlowski et al., 2001). That is, at a given moment, individuals are aware of a certain number of opportunities challenging them, 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 has been observed in many of the mobile learning projects mentioned above. In effect, the core part of the optimal flow experience can be briefly 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 motivated to work on longer learning tasks in the face of tempting distractions. Secondly, 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 content, in our case), filtering out irrelevant thoughts and perceptions. 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 experiences (Webster and Martocchio, 1992). However, learners are more motivated when the learning design generates *curiosity* and *interest* about the content and learning context. The Ambient Wood project and many game-based learning systems are examples that maximise these factors in instructional design.

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 (Park *et al*., 2010). However, this did not further articulate flow theory to encompass collaborative learning experience, which is central to this study.

2.2 Raising Challenge Levels: Social Flow

It is becoming 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 touted 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. The reason why we play or work on together seems quite intuitive – '*if you are playing (or learning) with other people, at least you might be contributing to someone else's happiness*,' which many social scientists and philosophers (e.g., Benthamites) have also concluded. Csikszentmihalyi (chapter 8, 1990) further maintained that the flow experience in either 'being alone' or 'being with others' might differ. 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.

We may establish a rather different view of this empirical approach to learning. Many game researchers have already judged the social game on its merits from the fact that people would join with others to tackle more challenging tasks. That being said, the relative levels of challenge and skill that the group will face together might be key to see the distinctive nature of *Social Flow* experience. Of course, we might be able to apply an individual's solitary flow to social flow experience as a whole, using a kind of simple arithmetic to add up pleasures and subtract unhappiness from them. However, people do not necessarily associate their own interests with the group's interest, and it would be wrong to say the total solitary flow experience of all individuals is equal to the social flow experience among all individuals in it. Therefore, the kind of social behaviour required for this collective flow experience has to be considered, particularly for learning activities.

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 normal range of ability. Recent biological evidence supports this contention, suggesting that team-play allows individuals to take on more risks and challenges (i.e., higher risk-taking social attitudes) than when working alone (Cohen et al., 2009). The benefits of mobile learning can be seen from this collaborative learning perspective. People in collaboration would have more opportunities to learn something in this social flow from the challenges taken by their peers. Hence, at a given moment, they can assess how they are capable of coping with these challenges together, lifting 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 do 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.

As to the concept of *social flow*, it is important to discuss Walker's work (2010), which addresses what happens when a group of people are absorbed together in a challenging physical task. In his first study, the participants thought more collaborative physical activities (e.g., playing football or walking in groups) were associated with more joy than solitary activities. 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 more emotions usually associated with flow experience, including feeling alive, focused and cheerful. Also, the participants with a 'high interdependent' relation to each other were rated as more joyful than the participants in the low interdependence condition. Crucially, the highly interdependent participants were still rated as more joyful even when the analysis was restricted to just those participants from each condition who had found their respective tasks equally challenging and requiring of skill. In other words, with flow experience kept as constant as possible across the two conditions, the more interdependent version of the physical activity still appeared to provoke more enjoyment. Thus it can be seen that people working together actually raise the levels of the challenge of a task. This triggering mechanism would explain why collaboration would increase their motivation, and as a result, the concept of social flow could be central to mobile learning research. This possibility has not been discussed in the literature, and 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 extend this new form of flow experience.

3. EXPERIMENTAL STUDY

The main purpose of this experiment was to explore whether collaboration via mobile devices could be associated with a rather different learning experience. If this is the case, then we seek to answer the different learning outcomes from social flow. To empirically examine this, it was necessary to examine a collaborative learning activity in a natural learning setting. This would allow one to identify how mobile technology achieves a critical collective learning objective, and eventually how the benefits of mobile learning may be naturally perceived by the contributing learning partners.

A simulated but realistically situated learning programme was thus developed to train security guards. 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 system – 'solitary' mobile, 'collaborative' mobile, and 'face-to-face' collaborative learning – were developed to assess the differences in both learning outcomes and flow experiences rated by the participants. All the systems allowed the trainee guards to participate in a security patrol mission by 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 arranged at Massey University, and each patrol location had instructions for the trainees to learn (Figure 1).

Figure 1. The system guided trainees to locations where they were given instructions.

The same six locations were used throughout the experiment, and each subject in the collaborative conditions (i.e., mobile collaboration and face-to-face collaboration) only visited three areas personally, to deliberately simulate a collaborative learning context. This experimental setting would jointly allow every pair to learn the six places together. The participants in the 'solitary' learning condition were asked to complete the six patrol tasks alone, as a control condition.

3.1 Participants

Forty-five trainee guards volunteered, none of whom had physically explored the premises before. They had a similar educational background, aged 20–28. Only five were for the solitary learning system control condition. The rest of the subjects were assigned at random to one of the two collaborative settings (ten pairs to mobile collaboration, and the other ten for face-to-face).

3.2 Experimental Design

The experiment was a between-subjects design. The three types of learning systems given were the between-subjects independent variable, while the dependent variables were the ratings on statements regarding the flow experience (see below); learning performance of how well each participant had learnt the patrol instructions from both their visit and their partner's visit (i.e., un-visited); types of knowledge generated (problem, theory, agreement-disagreement or suggestion) 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" as depicted in Figures 1, 2 and 3. The difference between the two collaborative systems is that the mobile collaboration supports instant exchange of text and photo messages between the trainees (Figure 2).

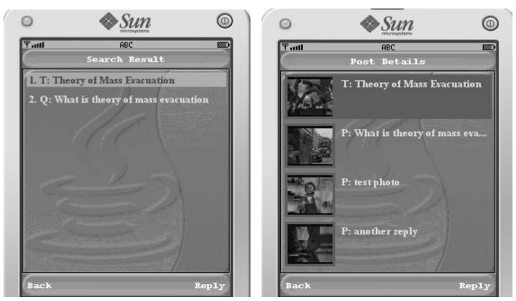
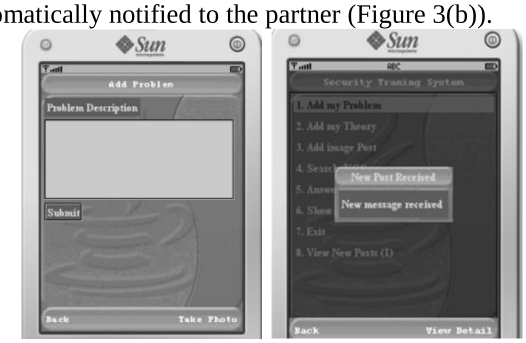


Figure 2. Text/Picture based collaborative communication.

On the other hand, the face-to-face collaboration only allows photos and uploads them to a server for their face-to-face collaboration just after their patrol. That is, the mobile collaborative system allows our participants to instantly communicate with each other (see Figure 3(a)), i.e., as soon as new texts or photos are added, they are automatically notified to the partner (Figure 3(b)).



(a) (b)

Figure 3. Working together each other. (a) Adding up new information; (b) As soon as new information is added, the partner is automatically sent the notification.

In contrast, the face-to-face collaboration does not allow this instant communication. As a counterbalance to this, trainees can take photos, upload them to a server, and later on view them together in a wrap-up session in order to give them the opportunity to externalise or build up the knowledge they want to share with their partner. We believe this time-delayed collaboration can present what is lacking in the collaborative learning experience, in terms of social flow and learning outcomes related to mobile learning.

To examine if the trainees had retained certain learning outcomes, a retention test was administered the next day, with six multiple-choice questions related to the six patrol locations. An important note is needed here. Each participant had physically visited only half of the six locations, so they had to answer questions about the un-visited places based only on their collaboration during the patrol (mobile collaboration) or the wrap-up session (face-to-face collaboration). Thanks to this manipulation, the retention test (i.e., if they could answer the half of the questions from their own learning, and the other from someone else) is expected to show the effects of mobile collaboration, if any.

The seven statements relating to flow experience were then rated on a five-point Likert scale. These were developed from the first author's previous work (2010), which suggested the benefits of mobile learning can be seen by the optimal flow experience aroused by '*cognitive curiosity*' and '*intrinsic interest*'. The last statement was inserted to see if working in a group would prompt them to tackle more challenging tasks, as a result of being further motivated. If this was the case, we would be able to see collaboration as a key benefit and thereby influence a trajectory of mobile learning curriculum development.

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

3.4 Procedure

Figure 4 shows the procedures for each experimental condition. All the participants attended a tutorial session that gave them the necessary information to carry out the experimental task, including the six locations to be patrolled and how to use the "Online Patrol Training System" (see Figures 1-3). In the main experimental session, they were told to visit the locations, find some security issues related to their visits, and, if required, to take photos of the site and describe the issues when submitting them to the database.

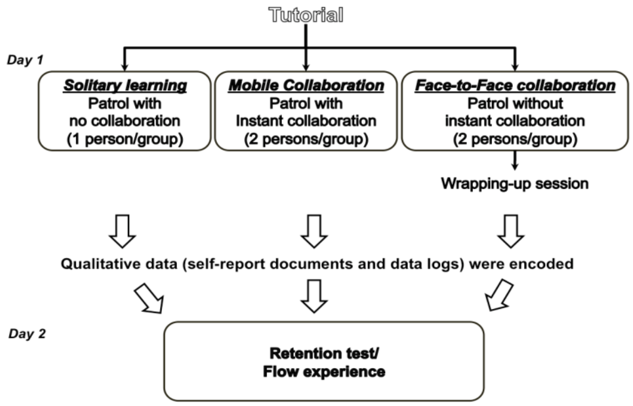


Figure 4. Experimental procedures. Note that face-to-face collaboration has a wrap-up session.

To ensure the quality of the descriptions of the issues (i.e., *knowledge*), 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 eliciting knowledge quite onerous. Hence, they were asked to use some '*scaffolding*' words, as used in the "Online Patrol Training System." Table 1 exemplifies two subjects contributing their opinions by using the scaffolding words.

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.

In contrast, for face-to-face collaboration, subjects were only allowed to take photos, and no immediate collaboration was available during the patrol. Hence, each participant only learnt about half of the six locations during their own patrol, and received no information relating to the other locations. As a compromise, 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 24" monitor was used to facilitate this collaboration process showing all the photos they had taken. The subjects were then told to use the same scaffolding words (i.e., problem, theory, agreement-disagreement, suggestion) to compile their knowledge and generate a document. All the experimental sessions were conducted pair by pair, and each pair completed the whole experiment in about one hour.

4. RESULTS

As depicted in Table 2, our participants in the face-to-face collaboration seemed to perform the experimental task poorly, when compared with the other two experimental systems. This might indicate limitations to this type of instructional design in training programmes, where physical visits or instant collaboration is essential. Note that the face-to-face 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 face-to-face collaboration, regarding learning about the un-visited places. Note that both systems asked the participants to visit the 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.

Table 2. Learning performance (Mean/S.D, max: 100).

System	N	Visited	Un-visited
MS learning[*]	5	91.90 (16.44)	-[**]
MC learning[*]	10[***]	89.85 (19.27)	84.70 (17.35)
FtFC learning[*]	10[***]	81.40 (23.11)	71.25 (22.554)
sig.		n.s	p≤.05

[*]MS – Mobile Solitary; MC – Mobile Collaborative; FtFC – Face-to-Face Collaborative; [**]Mobile (Solitary) learning asked the participants to visit all the six locations, as a control group; [***]10 pairs=20 subjects.

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

As another learning outcome, for mobile collaboration, participants' communication logs were recorded. For the face-to-face collaboration, the subjects met face-to-face 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, the researchers analysed the encoded data by using the verbal protocol analysis method. 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.

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 was not analysed here. Overall, the two collaborative systems did not exhibit much difference, except for agreement (disagreement) being significantly higher for the face-to-face group. A T-test confirmed this (t_{38}= -3.97, p≤.01). A possible explanation may be that the participants in mobile collaboration could check and interrogate their knowledge on the spot; on the other hand, the participants in face-to-face collaboration needed a heavy negotiation processes to build up a consensus in the wrap-up session.

Table 3. Mean frequency of each coding category

	Problem	Theory	Agreement (Disagree)	Suggestion
MC	4.20 (1.94)	5.65 (2.28)	1.13 (1.02)	3.30 (1.59)
FtFC	3.95 (2.30)	5.05 (2.21)	2.50 (1.49)	4.20 (1.64)
sig.	n.s	n.s	p≤.01	n.s

This interpretation was partially supported by inspecting the type of the 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 for being generated individually, without conversing or consulting with the other peer. 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 mobile collaborative learning system generated more knowledge from their collaboration, and this was assessed by a Chi-square test (χ^2= 14.18, p≤.01).

Table 4. Mean frequency of each coding category

System	Knowledge by collaboration	Knowledge without collaboration
MC	122	145
FtFC	72	172

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 experience, and possibly the implications of social flow. '*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 willingness to exploit the learning system further. '*Intrinsic interests*' can be termed as subjective experiences during interactions that are characterised by perceptions of pleasure and involvement. Higher ratings on these questions mean the learners are so intensively involved in the learning activity that paying additional time and efforts in the learning activity does not seem matter. 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 negative effects of collaboration such as the additional time and 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.

Table 5. Mean ratings of the flow experience

System	Cognitive curiosity	Intrinsic interest	Risk-taking
MS	2.52 (0.83)	2.71 (0.92)	1.35 (0.77)
MC	3.80 (0.77)*	3.88 (0.75)*	3.95 (0.89)*
FtFC	3.20 (0.95)	3.00 (1.08)	3.25 (0.79)
sig.	p≤.05	p≤.05	p≤.01

*For each contributor were averaged out to give one face value in each column; *Significantly different from the others by a Tukey test* at p≤.05

Table 5 gives the mean ratings for the three experimental settings across the two contributors to the flow experience. Arguably, the last item is considered as a mediator to bridge them for collaborative benefits. In all cases, collaborative mobile learning gives the higher ratings, which indicate our participants had somewhat different flow experiences in mobile collaboration. A one-way between-subjects analysis of variance was applied, followed by a Tukey test (at p ≤.05).

5. CONCLUSIONS AND DISCUSSION

When considering the impact collaboration has on a learning activity, our empirical data showed that when potential learners had manageable challenges, and they saw them as positive self-improvement opportunities, then an intention to collaborate was triggered. This was not the case in a solitary learning environment or time-delayed collaboration, where the participants can simply choose to "not learn" and maintain the status quo at no cost. This study also suggested the social flow experience effect as one potential analytic viewpoint from which to see the benefits of collaboration in mobile learning. Indeed, we posited that social flow might account for collaborative learning outcomes, but we did not actually form this hypothesis for the subsequent empirical study. Instead, we simply hoped to observe that potential collaborators are more likely to be motivated to learn together based on their shared situational goal orientation. Comparison of the three experimental configurations allowed us to pinpoint the potential value of the collaborative mobile learning experiences available in this context. The evaluation of social flow experience and risk-taking behaviour explicitly confirmed the significant advantages of collaborative mobile learning over the other formats.

Many educational practitioners have long believed that collaborative learning activities enable exchanges of thoughts, emotions, and ideas among learners (Childress and 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 main contributions of this article are to empirically demonstrate that this social flow experience can be maintained in collaborative mobile learning, and further that each individual's solitary flow experience cannot displace the group's collective flow experience.

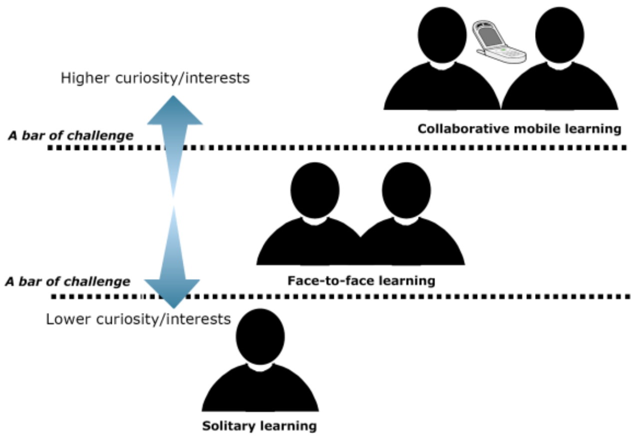


Figure 5. Social flow to raise the bar of challenge

Based on the findings discussed above, Figure 5 sketches out the concept of social flow, whereby groups can raise the level of challenge in performing a learning activity together. In such cases, learners are more motivated when the learning design generates higher curiosity and interest about the content and learning context. In that context, mobile learning would have the effect of uniting them together, in order to gain the collective flow experience by tightening social bonds. That is, collaborative partners with the same learning goal orientation can have adaptive responses to new and/or challenging situations. 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.

The results of this study also raise several questions that could be pursued, and the limitations of this study need to be fully addressed in future work. For instance, 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 social flow experience effect in collaboration. Social flow is a concept that has only recently come to the attention of learning researchers, but there is much potential in further exploration of its implications for collaborative mobile learning.

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