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FlipMe: A Tangible Approach to Communication in Online Learning

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Online learning continues to see rapid growth with millions of students now engaging in online and remote courses as convenient alternatives to conventional classroom-based teaching. Despite these advantages, online courses suffer from high drop-out rates. Prior research has suggested the limited opportunities for social interaction between students may contribute to these undesirable outcomes. In order to address this challenge, we developed FlipMe, an Internet of Things companion augmenting peer-to-peer interaction in real time. We then conducted a pilot user study to explore the potential of FlipMe as design intervention to increase peer-to-peer learning while watching online video content. Initial findings indicate FlipMe's tangible interface and feedback have the potential to promote peer interaction in online learning. We close by discussing directions for future work.

Keywords: Online Learning; Tangible Interface; Product Design; Communication

1 Introduction

Online learning services, defined as any form of learning conducted partly or wholly over the internet (Shah 2017), are growing in use and popularity. These include both MOOC (Massive Open Online Courses) learning platforms and independent sites and tutorials that are ubiquitously available through social media sharing venues. However, online learning, and its associated platforms for communication, face many crucial challenges. Notably, dropout rates in online learning far exceed traditional, classroom based equivalents. Approximately 90% of all students do not complete their online course. This is largely due to low student engagement and the challenges of self-motivated learning activity (Lu et al. 2007). Moreover, students studying in online learning environments, such as Udacity (Udacity Inc. 2019), Coursera (Coursera Inc. 2019) and Khan Academy (Khan Academy, 2019) suffer from a lack of communication with peers because the individual online learners in a peer group are remote from one another. In addition, compared to a traditional classroom context, most online learning platforms provide dramatically lower student to instructor ratios. Both communication with peers and receiving feedback from instructors benefit students' learning experiences (Hong Lu 2007); the lack of these features in otherwise accessible and convenient online learning systems contributes to high dropout rates.

Peer learning activities, described as any learning that involves multiple students studying from and with each other to attain educational goals (O'Donnell 1999) can improve students' engagement and the quality of the overall learning experience (Ahn et al. 2013). Likewise, previous studies reveal social factors influence students' expectations of peer learning (Boud et al. 2014). Thus, social interaction with peers appears fundamental to achieve higher completion rates in online education programmes (Cercone, 2008). Research has suggested that online social activities, such as discussion in forums, are far less effective than the more personal and interactive communication provided in traditional classroom contexts (Thomas, 2002).

The tangibility of real world objects, experiences and social interactions may contribute to the effectiveness of classroom learning. Tangibility plays an important role in people recognizing and affecting their environment (Johnson, M, 1987). It is also an effective channel though which to convey information to and between people in memorable and intuitive ways via physicalized data (Zhao, 2006). As Zhao (ibid) argues, these more impactful representations of information can directly change user behaviours. Based on these observations, the current study explores how interaction with a tangible product representing the activities of a peer, online learner can improve opportunities for social interaction to motivate students to engage with their peers during online learning.

2 Interpersonal Communication through Tangible Interaction

The current study aimed to physicalize learning activities through *data physicalization* (Jansen 2015). *Data physicalization* is beneficial for leveraging our perceptual exploration skills, facilitating understanding and learning, bringing data into the real world and fostering public engagement in the number of favourable situations (Yvonne Jansen, 2015).

For example, an early study by Ishii (2001) used 40 computer-controlled pinwheels to present ambient information of human's activities, such as physical movement: walking or online activity like emailing. If the system detects an email containing a large volume of attached files, several pinwheels spin, while only a few pinwheels spinning indicated smaller sized emails. Likewise, CalmStation (Kim 2017, Figure 1, left) allows users to remain focused while conducting desk work. While LOOP (Sauvé et al. 2017) introduces a physical artefact that changes its shape according to the activity data of the owner (Figure 1, right).

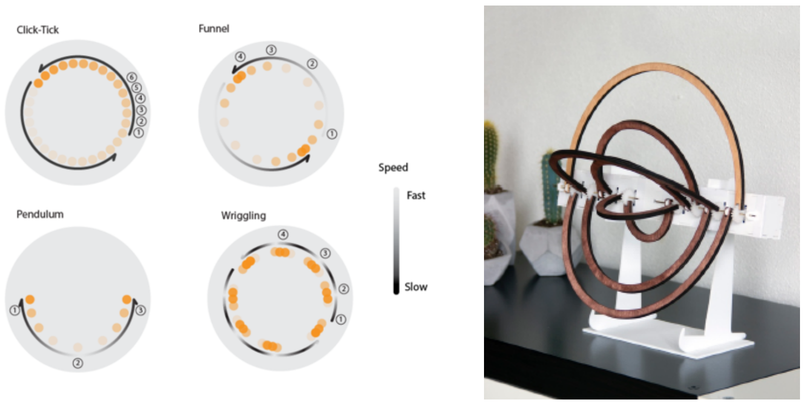


Figure 1. Examples of abstract and reflective information through not disturbing interaction methods. Calm Station (left) and Loop (right)

Both examples provide abstract information with simple product compositions. CalmStation (op cit) demonstrates various types of mobile phone notification through the speed and pattern of the rolling ball, while LOOP provides activity data gathered by trackers, such as smart watches.

Further early work by Strong & Gaver (1996) describe three experiments in designing in support of implicit, personal and expressive communication. Feather (Figure 2, left), is constrained by a transparent plastic cylinder, lifting and falling by air pressure as the paired partner touches an interactive picture frame. More recently, the Indoor Weather Station (Gaver et al. 2013, Figure 2, right), consists of a tiny ‘forest’, made of paper, enclosed by a transparent, miniature pavilion. Once the station detects wind, it controls a small fan inside the forest’s enclosure, which amplifies the gusts to create miniature storms that visibly blow the ‘trees’. While not concerned with communication, Gaver et al.’s (ibid) forest concept exemplifies the ways in which tangibility may be used to express a change or feedback (trees moving) related to an action (wind).

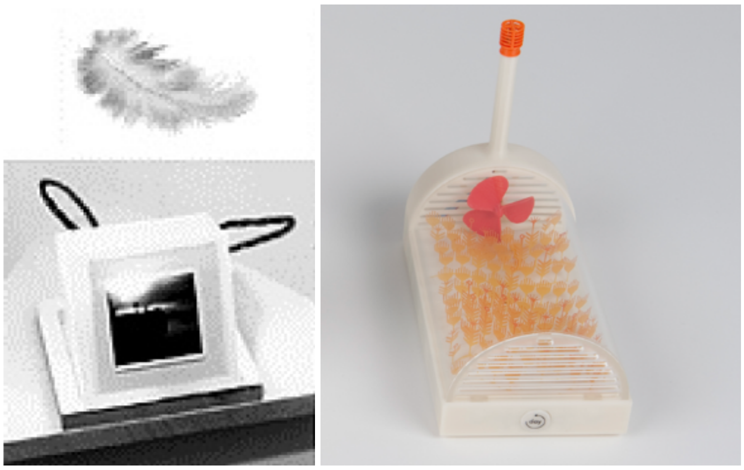


Figure 1. Feather(left) and Wind Tunnel(right)

In terms communication more specifically, InTouch (Brave & Dahley 1997) provides a physical communication channel between people in remote locations. Two geographically distant people may cooperatively move, fight over the rollers or feel the other person’s manipulation of the roller (Figure 3).

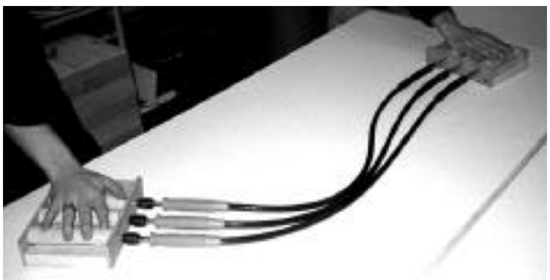


Figure 2. Prototype of InTouch design

Tactile communication appears beneficial for expressing emption. In addition, interpersonal communication through tangible interfaces has been shown to convey enjoyable experiences (Jones & Yarbrough 1985).

3 Preliminary User Interview Study

The purpose of an initial user interview study was to explore how students study in online courses and affect each other through communication and discussion online. These insights were then used to drive the definition of design requirements.

For this research purpose, we conducted semi-structured interviews with 3 graduate students aged from 26 to 28 years old (2 female, 1 male), two university tutors and one high school tutor aged from 32 to 33 years old (2 female, 1 male). Although the complete interview process, analysis and results are not reported here, Table 1 provides an indication of example interviewee responses, insights gained and application as design requirements to drive the design and development of a tangible product design concept we term FlipMe (Table 1).

Table 1. Design requirements derived from preliminary interview study

Participants' verbatim	Insight	Design requirements
I feel uncomfortable… some responsibility if I don't watch video lectures because I may affect negatively my team member.	Social responsibility plays important role in motivating video content watching watch	1. Design must provide feedback on progress of group members
We pin our works on the wall. At that moment, I care a lot not only about their (peers) comments but also micro things such as whispers, Wow sounds and so on. This helps me to evaluate my own work.	Micro/non-verbal interaction (with peers) stimulates student reflection on own works	2. Design to provide micro interaction opportunities. i.e. nudge, whisper, body language
I feel I'm the only one spending my time in front of the computer to watch the lecture. In contrast, I feel better if surrounded by my colleagues, taking lectures together.	Peers motivates peers to engage more in online lectures. Presence of colleagues in same time/space motivates learning	3. Design must accommodate peer-to-peer motivation through simulation of working in same time and/or space
Group work is significant but there is no answer to make a perfect group…always mixing members up if some show poor performance may help. It's because individual students learning styles are all different.	Learning styles affects teamwork and potential cohesion of teams	4. Design needs to provide opportunity for matching learning style to improve collaborative learning

4 FlipMe Design & Development

4.1 Design Features

FlipMe is an IoT (Internet of Things) concept, aimed at augmenting peer-to-peer interaction to promote more active online learning (Figure 4).

Figure 4. FlipMe online learning companion

We designed FlipMe through metaphors, with the objective of at reminding users of learning activities familiar with student (Casakin & Hernan 2007). In this we aimed to provide the predictability of the novel interactions. For example, flipping book pages and sharpening a pencil in a learning context (rotating handle design). A flipping-top provides real-time feedback on peer study activities through its *reading-a-book* like motion (Figure 5).

Figure 5. Peer-to-Peer communication promoted through FlipMe's tangible approach to interaction and data physicalization

Group study activity is expressed through a *rolling-ball* feedback to the product's front (Figure 6). A rotating handle provides a peer-to-peer nudging function. All three features were designed to motivate students' social interaction, which was identified as of significant importance in online learning (Nisbet 2004).

Figure 6. Rolling-ball indicates group (class) study activities towards online class works

4.1.1 Real-time Feedback on Peer Learning Activity
Through FlipMe's book-flipping metaphor, students inform peers of online learning activity. When a paired colleague begins to view video content the personal learning companion starts to flip. This design feature was derived from the requirement to motivate working together.

4.1.2 Tactile Interpersonal Communication
FlipMe provides an opportunity to communicate between peers. A user may rotate the handle when (s)he wishes to start learning together and/or discuss educational contents. As a user rotates the handle, FlipMe transmits the same number of spins to the friend's flipping top, thereby indicating to peers that they are studying (Figure 7).

Figure 7. Rotation handle (bottom-left), inner mechanism for flipping top (top-left)

4.1.3 A Common Goal Indicator

A ball placed in the front face of FlipMe moves to indicate when one or more class peers are viewing video content. The goal-oriented visual presentation also meets goal setting theory proposed by Locke & Yarbrough (2001) that indicates the importance of evaluating progress towards learning objectives. When the deadline of certain course sections ends, the ball moves back to its starting position and the collaborative race will begin again.

4.2 Design Prototyping & Implementation

All parts of FlipMe were designed using CAD (Computer Aided Design) modelling subsequent to ideation through sketching and illustration. Based on material and/or complexity of shapes, we utilized different fabrication techniques in the production of a high-fidelity prototype that aimed to approximate, in detail, aesthetic and functional characteristics.

A 3D printer (Objet Eden 260) was utilized for complex shapes or parts, which were subsequently finished in colour spray paint. FlipMe’s plate type components were fabricated by laser cutter (Universal laser system), while CNC (Computer Numerical Control) was utilized for the manufacturing of FlipMe’s wooden base and leg parts (Figure 8).

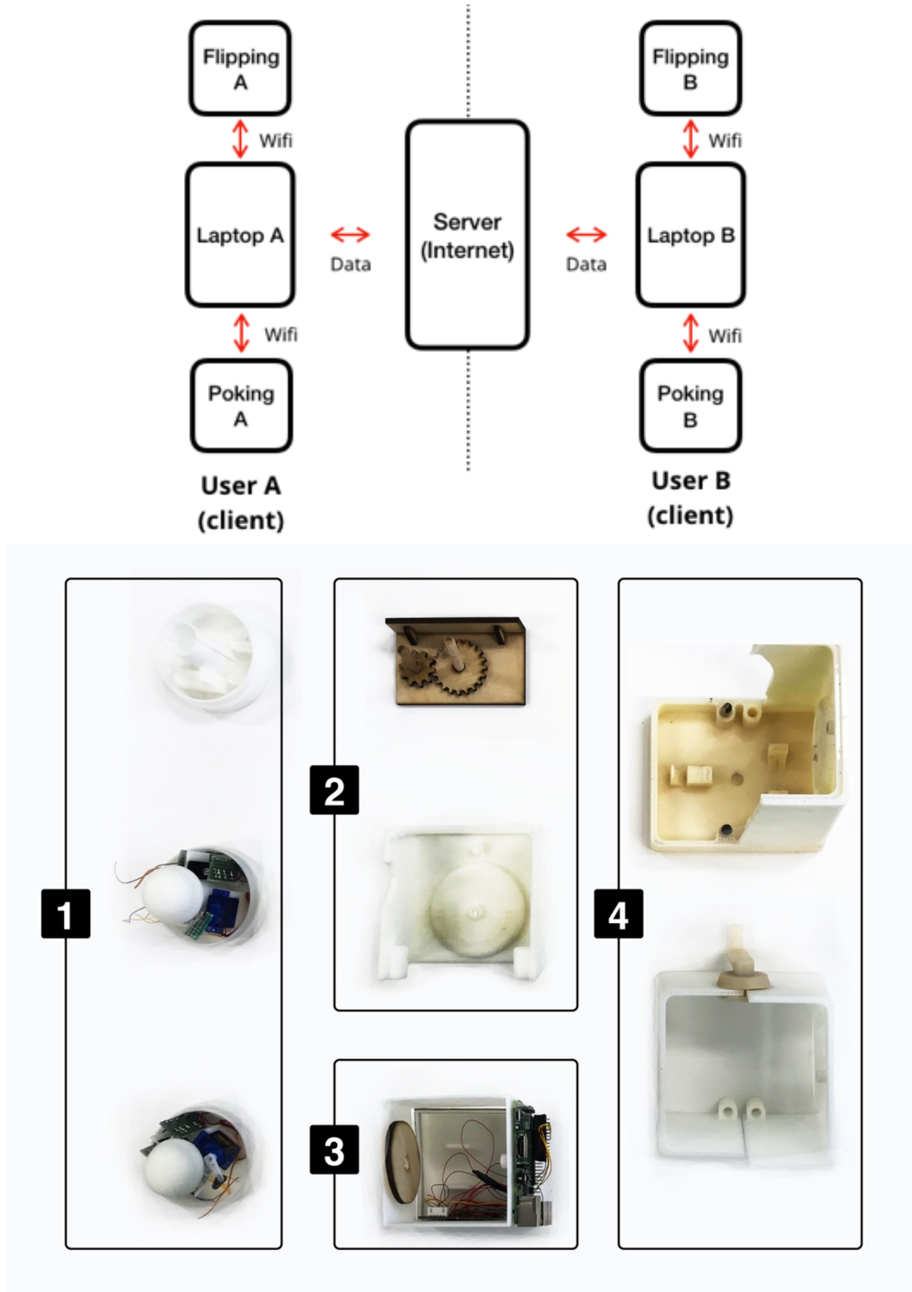


Figure 8. Initial system communication design. Iterative prototyping process: product divided into each interface type. 0)'Poking' prototyping, 1)Common goal indicator prototyping, 2)'FlipMe' 1st generation and 3) Housing structure of FlipMe 2nd generation.

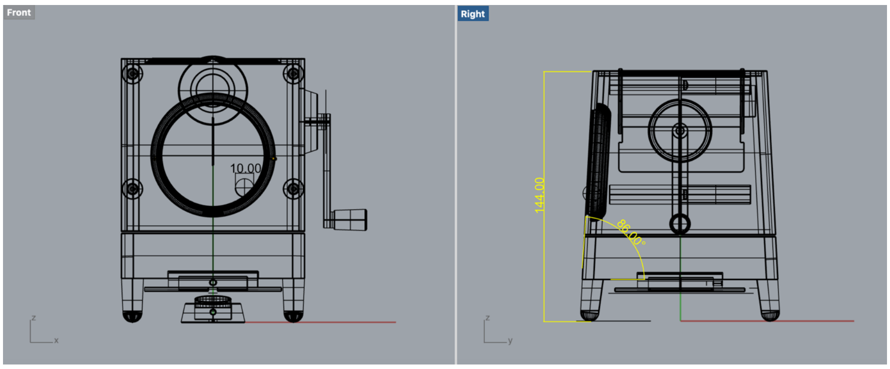


Figure 9. Front and side view of CAD modelling of FlipMe 2nd generation

The main body was designed with a height (144mm, including legs) and an inclination (86°) (Figure 9) so that a user could more easily observe the main interfaces on top and in front. he parts were painted through surface air spray (TESTROS enamel spray, Figure 10).

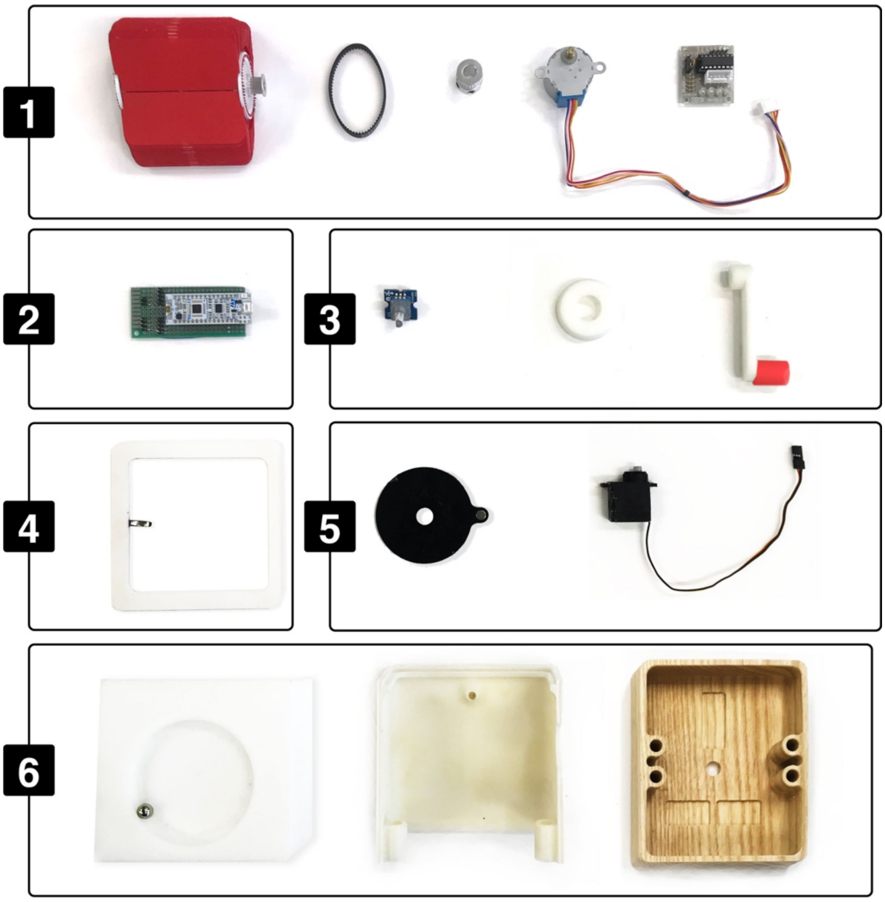


Figure 10. Components of FlipMe prototype: 1) flip cards, timing belt, pulley, step motor and step motor driver, 2) MCU with Wi-Fi module, 3) Handle components with rotary encoder, 4) Rid with a flipping card holder, 5) a magnet holding plate for common goal indicator and a servo motor, 6) Front housing and wooden body

A neodymium magnet with a diameter of 8mm was used to provide information on the progress of the common goal to the front side of the body (roller-ball feedback, Figure 7 above). The neodymium magnet was installed to roll along a circular embossing area of 64mm in diameter. In order to implement the movement of the ball type magnet, two gears with a gear ratio of 1:1 and diameter of 32mm were laser cut and plugged with 180 ° servo motor. A plate with cylindrical magnets was installed on the backside of the circular embossing area. As the servomotor starts to turn, the plugged gear turns, transmitting the rotation to another gear installed with the plate on the back side of the circular embossing area. Consequently, the cylindrical magnet on the backside of the body rotates the ball-shaped neodymium magnet.

To design FlipMe's flipping card feedback feature; a flip clock's mechanism was used as a reference. 1mm polycarbonate sheet was selected and cut by laser cutting (5% power 5%, speed 4%, PPI (500), 1.00mm). A mat red finish was finally applied to the flipping card parts (Figure 11). A small aluminium needle (0.3mm diameter) was designed to hold and release the flipping card. In total, 48 finished cards were used to provide information on peer's learning activity. Finally, to rotate the cards, a timing belt (130mm) and pulley (15cogs, ⌀5mm) was used as power-train from a stepper motor.

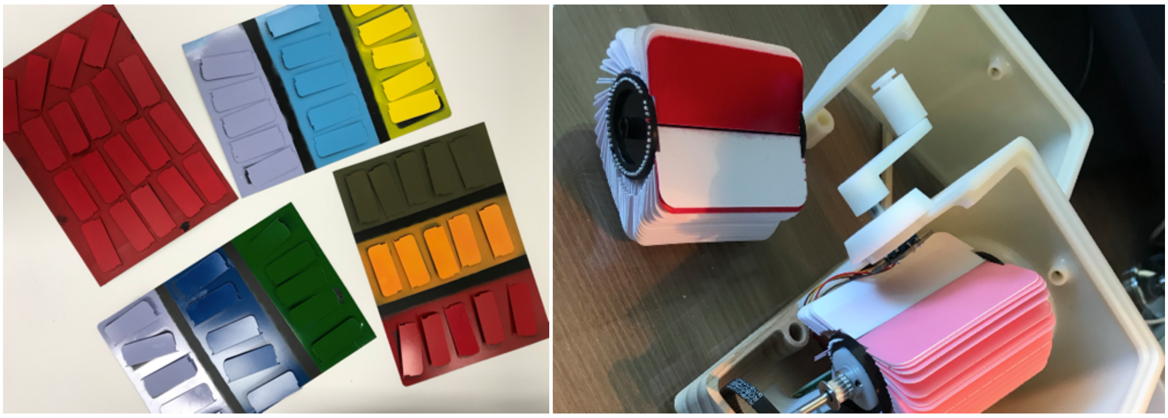


Figure 11. Flipping cards' color variation trials and cards holding mechanism

The interior design of the handle was considered to install a 360° rotary encoder module (Grove-Encoder) which senses the number of rotations of the handle through the digital control board (Nucleo L432KC). This provided the same pattern/number of rotating to a paired FlipMe product. Ash was selected to provide the natural beauty of the grain. In order to prevent the breakage during CNC machining, a minimum thickness of 6mm was maintained. FlipMe's wooden legs were inclined to 82°. A 3D printed cable holder also was installed to FlipMe's wooden base. The most basic task was to send data to the server, that existed on the internet, and the real-time transmission and reception of information between paired FlipMe prototypes. The server thus communicates with the internet server at intervals of at least 2~4 secs. In the case of the handle, its rotating pattern is divided into 10 levels and recorded by the user's input as one rotation per second. The data is immediately reported to the Internet (*'rotation angle' per 1sec.* Rotation index ≡ $\left\lfloor \frac{\mathrm{degree}}{36} \right\rfloor + 1$, 0~17 degrees= 1,18~35 degrees= 2 ...342 degrees~359 degrees= 10).

The server was built on Node.js Express. It supports the hosting two websites (one for each peer) and also communicates with each peer's FlipMe device, providing the appropriate commands to the device or website according to the experimental environment.

5 Pilot Validation Study

Through a pre-set learning environment and a given learning task, we conducted an initial in-lab validation study to assess the value of FlipMe as an intervention for increasing peer-to-peer interaction during online learning. Although we report the results of a relatively limited pilot study here, the findings provide initial validation of FlipMe's potential. Specifically, the pilot aimed to explore the extent to which subjects were provided increased awareness of a peer's study activities (viewing video content), and to what extent this may result in behavioural change in terms viewing of video content. Would the spinning handle interaction/flipping-book/roller-ball feedback result in increased collaboration between peers?

5.1 Participants

The experiment was conducted with 22 student participants (*n=22, 22-32 years old, 8 female & 14 male*). All subjects were full-time, undergraduate students studying at the authors' specialised research institution in the Republic of Korea. All had experience in online education and were asked to complete Kolb's (2005) learning style questionnaire. We measured participants against Kolb’s (ibid) learning styles to explore how learning style may implicate communication between peers (Neese, 2016). Since the experiment was designed to observe peer-to-peer interaction, participants were asked to choose a peer and to participate in the experiment as a pair. Four pairs were assessed as exhibiting the same learning styles, while six possessed different styles (Table 2).

Table 2. Participants' learning styles

Participants	Learning Styles	Learning Style Correspondence
P1 – P2	Assimilator – Assimilator	Same
P3 – P4	Diverger - Diverger	Same
P5 – P6	Assimilator - Converger	Different
P7 – P8	Accomodator - Assimilator	Different
P9 – P10	Assimilator – Assimilator	Same
P11 – P12	Converger - Diverger	Different
P13 – P14	Assimilator – Accomodator	Different
P15 – P16	Diverger – Assimilator	Different
P17 – P18	Diverger - Converger	Different
P19 – P20	Accomodator – Accomodator	Same

5.2 Study Design

Two fully functional FlipMe prototypes were connected through an internet server. The pilot study was conducted between two independent spaces to provide an opportunity for participant pairs to remotely interact (Figure 12). The independent space assigned to each individual was a cube-shaped booth, with a whiteboard wall for recording notes. Each cube contained a FlipMe prototype, a desk, a chair, a personal computer (MacBook Pro, Apple), A4 writing paper, a pen, pencil and highlighter, post-it notes and a multi-plug. A camera was installed on the ceiling of the cube (Figure 13).

Figure 12. In-lab experiment setting

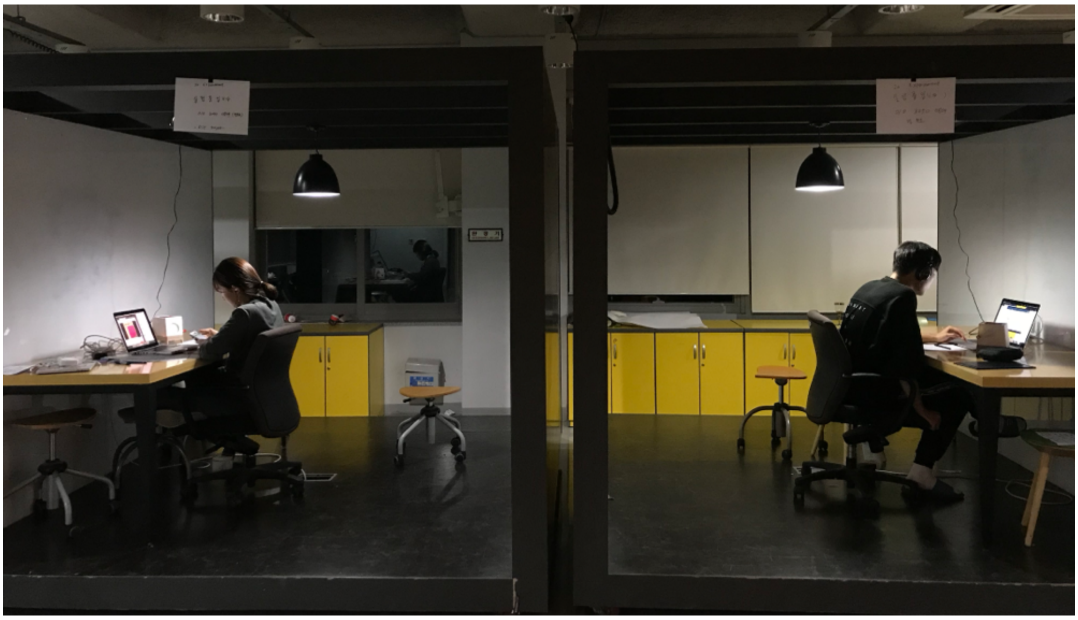


Figure 13. Independent participant booths

After an explanation of experiment aims, we provided participants the results of their learning style survey (Figure 14). At the same time, subjects were given time to share stories related to the task for 5 minutes.

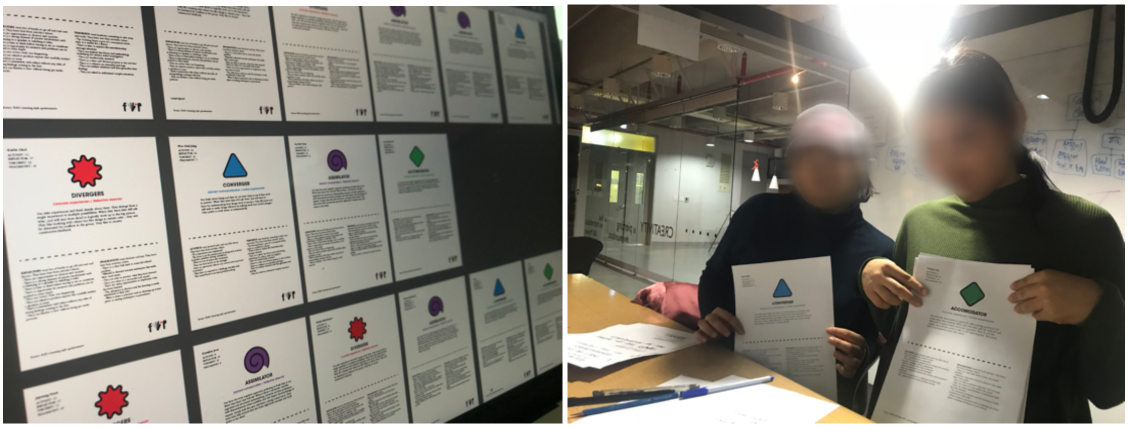


Figure 14. Learning style results for team building and for ice breaking at the beginning of the interviewing

Participants then entered their respective booths and were given 60 minutes to complete the assigned task. A 24-minute video (Norman, Simsarian & Glasson 2019) was provided as a source to help subjects address the provided questions. Questions were open-ended, essay type questions designed to stimulate discussion between peers. The length of the video content was set to be similar to the length of Pope’s (2015) previous study exploring the dropout rate of students during video viewing. Although provided, watching video content was not prescribed as a condition or rule. A post-session debriefing was run at the end of the sessions. In this final section of the study, participants were asked to share their responses to the given questions, their use of FlipMe and any challenges and/or opportunities experienced in terms of communication. Interview questions are presented in Table 3.

Table 3. Retrospective interview question design

Questions	Follow-up Questions (indicative)
Q01Do you have recent experience watching online educational content?	What was good or bad?
Q02 How do you normally watch/read given content?	Why do you…? Any issues faced?
Q03 How do you normally communicate/discuss regarding the course with your friends on/offline?	Why do you prefer…? With what purpose do you normally? Any inconvenience in online discussion?
Q03 Can you tell me any particular behaviour to watch (educational) video content?	Why do you prefer this…?
Q04 What activities did you engage to resolve the problem at the beginning of the task?	Why? Was it effective?
Q05 Did you complete the provided video?	From when? In what context did you start? Can you describe at that moment?
Q06 Have you used the handle?	Can you describe the moment you used the handle? Why you want to use? What have you felt? Any suggestion?
Q07 Can you describe when the ball started to move?	What was your reaction? Why? Any suggestion?
Can you rank among three main motions: flipping when the peer is watching, flipping with pattern when the peer is spinning and the ball location?	Why it was the best for you? With that, what have you done/felt? Why it was the least satisfying? Any suggestion?

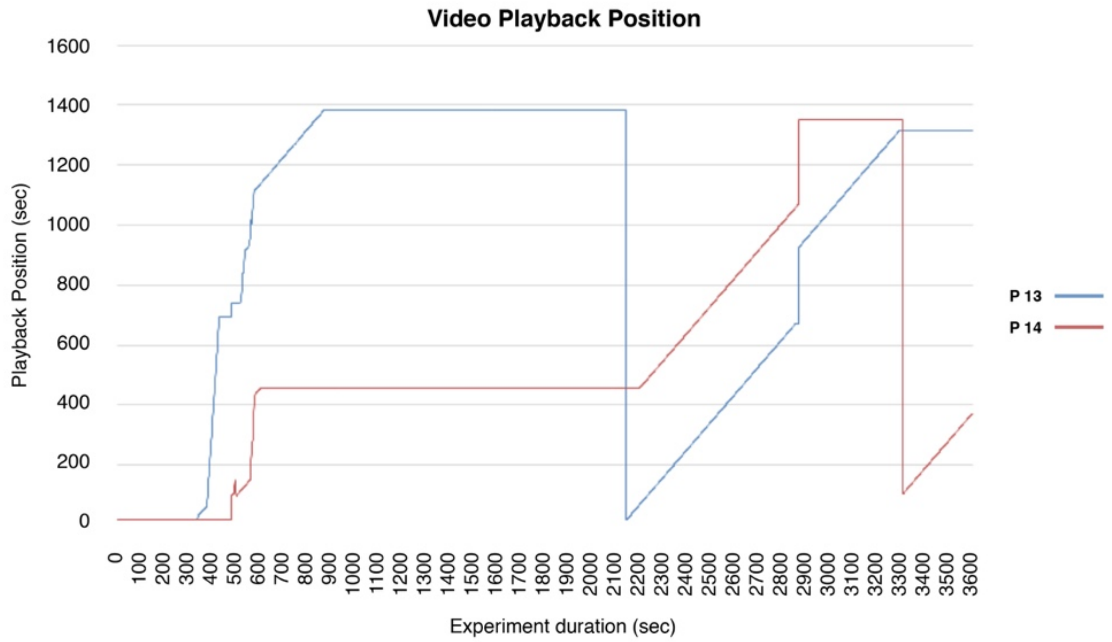
5.3 Product Interaction data logging

Data was logged from two sources for about 1200 minutes. Both types of data were logged to AWS (Amazon Web Service). The source of the data logging was the YouTube player link connected to the internet server and the rotary encoder of FlipMe's handle. The data log gathered from FlipMe was sent to the digital control board and, through the Wi-Fi module, delivered to an online server.

The raw data logged by a single user included: the number of connected users (1, 2), the user ID (*User1, User2*), the current video playback interval (*0-1440 seconds, total 24 mins*) video play status (*during playback, stop*), the spin frequency (*f*) and message frequency (*f*). All data types were reported every second based on KST. In addition, text message frequencies (participants using own PC and/or device) were logged in Slack (Slack.com), a professional communication platform's chatting room. Quantitative, interview response data was also collected through voice recording, followed by transcription and analysis.

6 Results

To explore if physicalizing peers' learning activities through the tangible interface (handle turns, flipping-book/rolling-ball feedback) motivated participants towards increased communication while engaging the provided video content, we compared handle spin frequencies (*f*) and video playback time (sec.) between paired peers. Figure 15 illustrates relations between video content playback and handle spin frequencies for a pair of participants (P13 & P14).



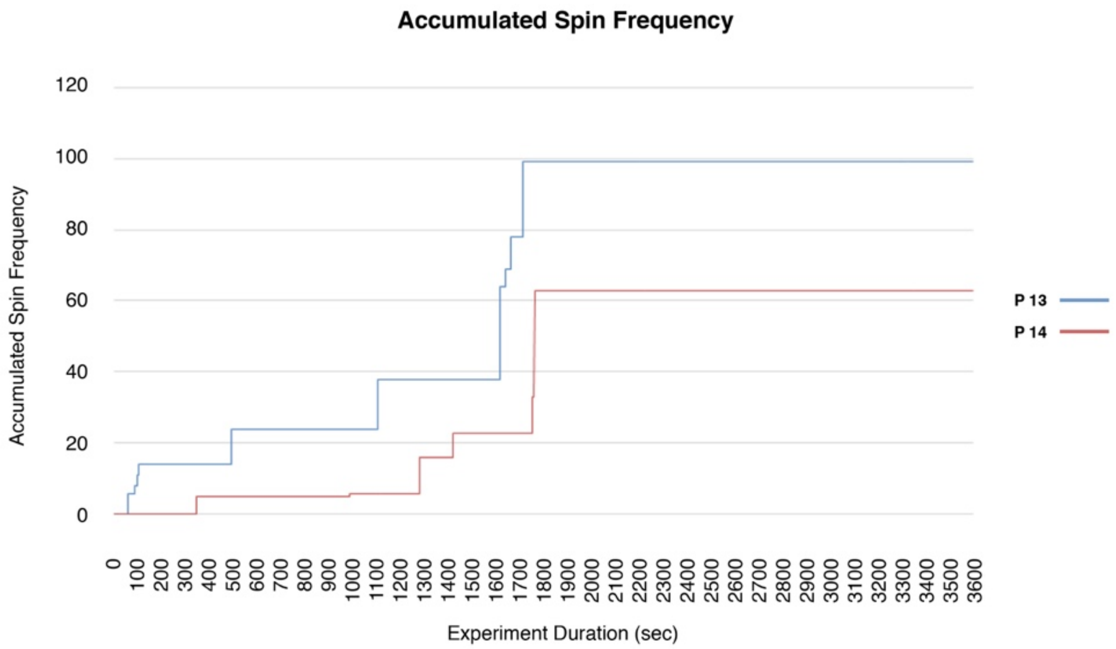


Figure 15. Line charts illustrating video playback timing and durations (above), and Spin frequencies (below) for participant pair P13 and P14.

The line graph above (Figure 15) indicates video playback position (vertical axis) and the session time in seconds (horizontal axis). The graph below shows accumilated spin frequencies (*f*), vertical axis, and session timing (horizontal axis).

As indicated the graphic expression of video playback position, at 350 seconds into the session P13 starts to view video content (Figure 16). P13 also starts to rotate FlipMe's handle just after the start of the session (see Figure 17 below, blue-line, 50 sec.). P14 starts to play video content shortly after P13 at 500 seconds (Figure 16). P14 also starts to spin FlipMe's handle later than P13 (see Figure 17 below, red-line, 350 sec.) and at a slower rate (3 spins). It may be that P14 responded to the flipping-book feedback with a handle spin of his own, before commencing video watching. This indicates that the flipping-book feedback as a nudge for a paired peer resulted in a return nudge followed by the commencement of video watching.

From 350 to 850 seconds of the session time P13 watches 0=1400 seconds of video content (Figure 16). The speed at which the content is viewed indicates P13 increased the speed of video playback, and/or scrubbed through the content. From 850 to 2150 seconds P13's video remains of 1400 seconds of playback.

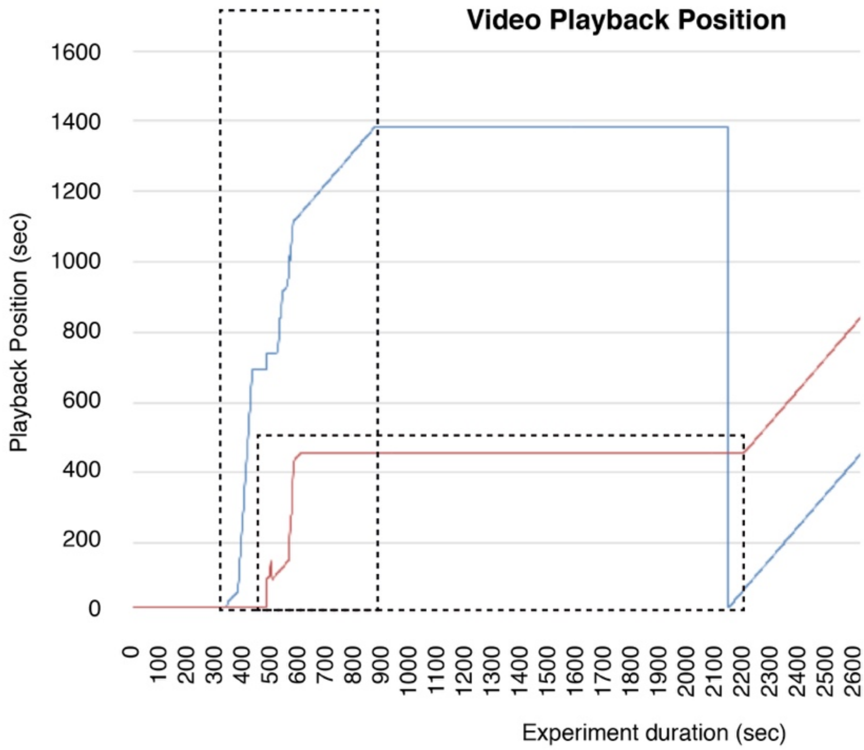


Figure 16. Playback of P13, 330-770sec and P14, 440-550sec.

In contrast, from 500 to 650 of the session P14 views up to 430 seconds of video content and pauses the video until 2250 of the session time (Figure 16, red-line). In the same period, both P13 and P14 give three further spins of FlipMe's handle, following a pattern of P13 spinning first, followed by P14 (Figure 17).

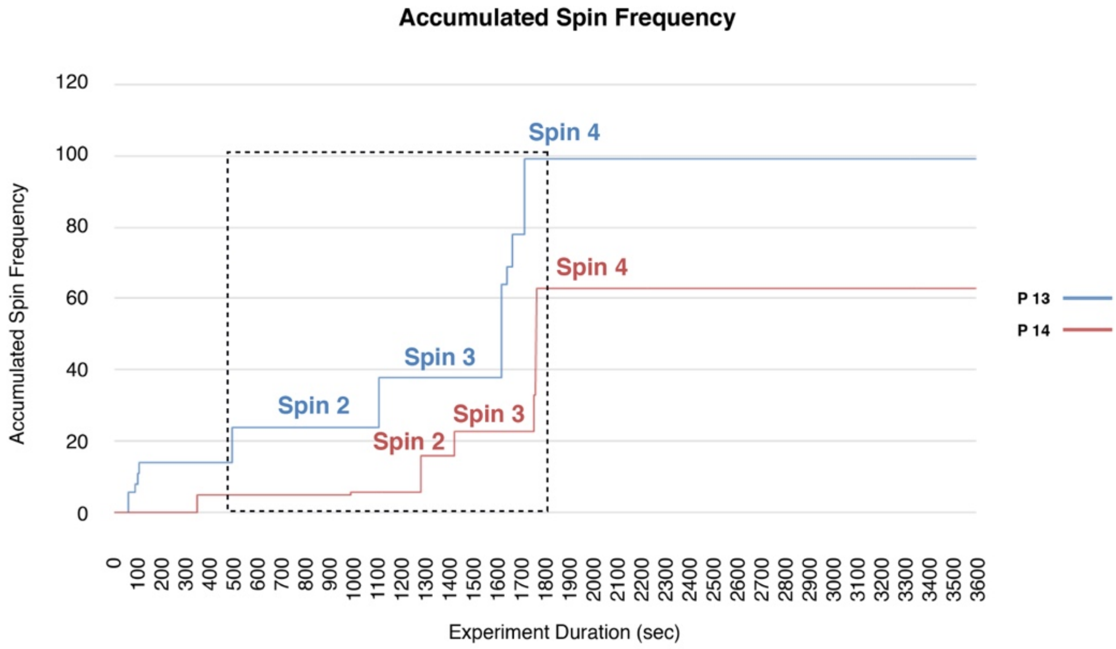


Figure 17. Handle spin frequencies

Despite the intensity of spinning frequencies by both P13 and P14 between 350 and 1800 seconds of the session, both P13 and P14 remain on 1400 second and 430 seconds of video content respectively until, at 2200 seconds, P13 re-starts playback from the video's beginning (Figure 18).

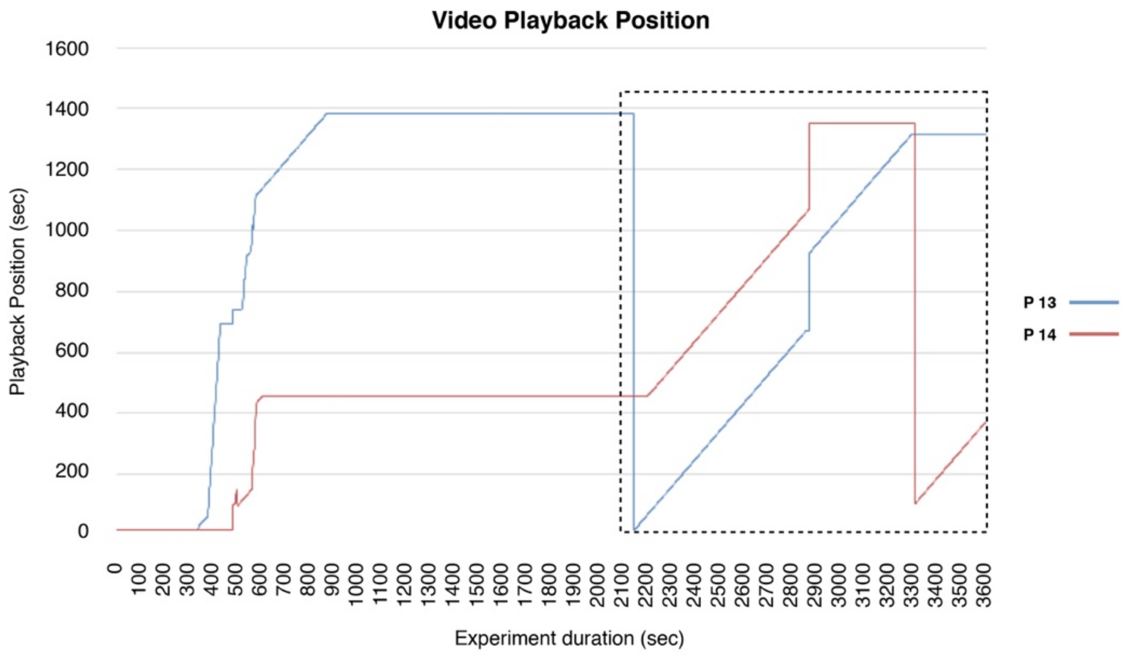


Figure 18. Re-commencement of video playback. P13 at 2150 sec. P14 at 2200 sec.

This is followed by P14, who commences video watching again at 2200 seconds of the session time (50 seconds later than P13). P14 continues to watch video content up to reaching 1070 second of the video, before scrubbing through to 1380 of playback at the 2900 second of the session (Figure 18, red-line). At 2900 seconds, the same time as P14 scrubs forward through the video, P13 also scrubs through to a similar playback position (Figure 18, blue-line, 970 sec. playback position). P13 then continues to watch video content up until 3300 second of the session and the 1350 second of playback (Figure 18, blue-line). At the same time in the session (3300 sec), P14 scrubs back to the start of the video and commences playback again from the beginning (Figure 18, red-line, 3300 sec.)

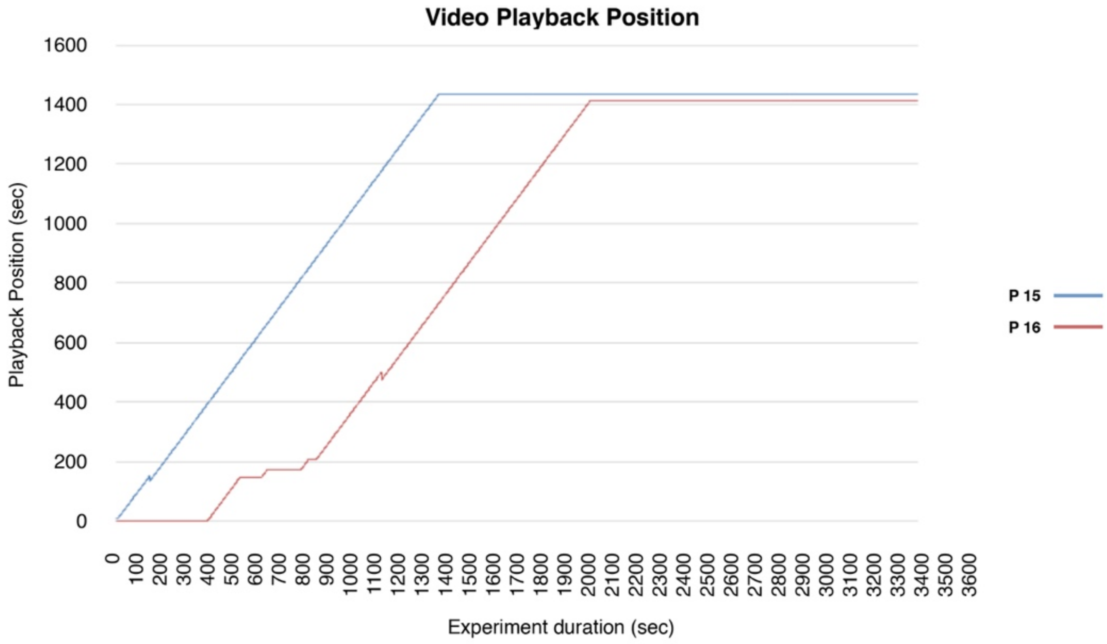
An analysis of post-experiment interview data indicated how the use of FlipMe's spinning handle nudge feature and associated flipping-book feedback may have stimulated P14 to engage video content under pressure from P13, '*At the beginning of the experiment, I, actually, was watching 'YouTube' game channel. But I felt that I also need to study once I realise my friend is studying.' (P14).* The use of social media (messaging) was also found in communication between the pair. For example, P13 explained, *"I spun the handle first then my friend sent a message to ask the reason for spinning. Then we started to chat about the product first and then about the video.'*

Taken together with the analysis of video watching and spin frequencies in relation to time in the session, these results illustrate the ways in which FlipMe worked as stimulation to engage in the video content. However, the subjects' interest appeared first focused on the novelty of the interaction/feedback (possibly explaining the appearance of spinning in the session's first half). In particular, the tangible interaction and flipping book feedback were appreciated by P13, '*The feeling of passing through the book through analog way added sensitivity.'* Likewise, P14 indicated a positive emotional response to the product, *'I do like the chewy sound as cards were flipping, it was white noise for me'.* For P13, feedback on the benefit of communication through FlipMe, resulted in increased efforts to interact through the FlipMe product, '*When my friend replied that my handle action worked on him, I continuously rotate handle to see my friend reaction.'*

However, 6 participants remarked on the distracting sounds from the device. Any future version needs be carefully designed to minimize noise production. In addition, it is not clear to what extent communication through FlipMe was related to the novelty of tangible interaction. The initial interaction through FlipMe did, however, facilitate further discussion towards the video content, resulting in some peer pressure to engage in both discussion of the materials and its viewing, '*I sent a message about our task to her (P13) then turned the handle, or turned the handle then sent a message.' (P14).*

On the other hand, such mutual communication between peers did not always occur in all subject pairs. For example, Figure 19 indicates no attempt to engage a peer through the

FlipMe interaction (P18, red-line, below, spin frequency).



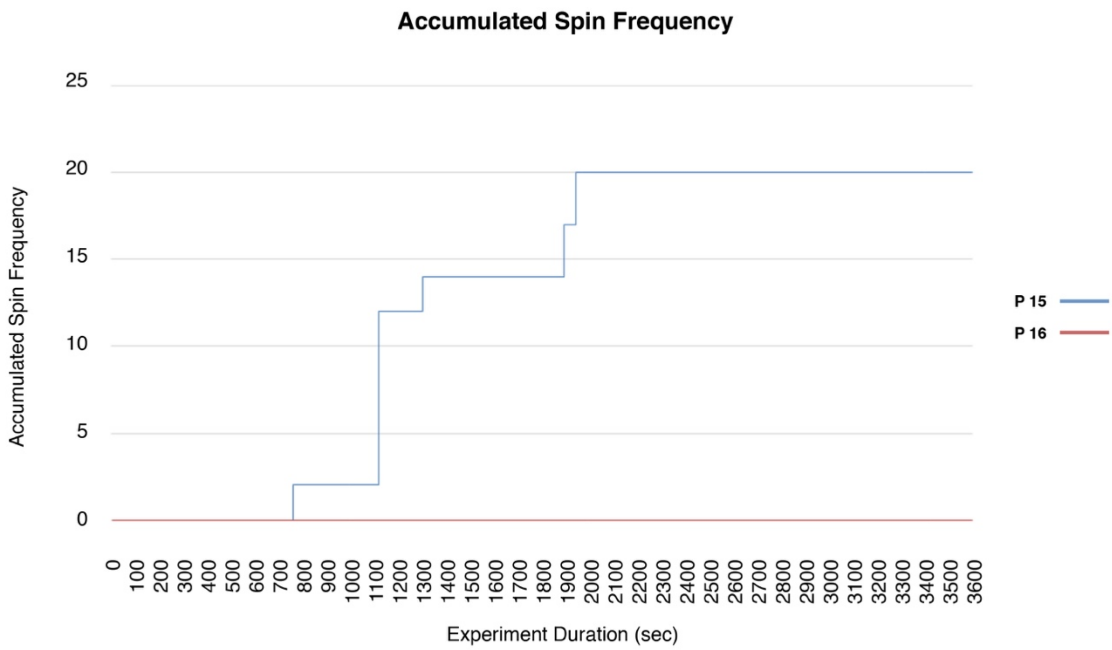


Figure 19. Line charts illustrating video playback timing and durations (above), and Spin frequencies (below) for participant pair P15 and P16.

In this session, unlike that of P13 and P14 illustrated in Figure 15 above, video watching commences for P16 at 400 seconds of the session and continued until 1200 seconds, whereupon the video's end was reached at approximately 2000 seconds. (Figure 19, above, red-line). P15 did attempt to communicate with P16 five times over the course of the session (Figure 16, below, blue-line stepping). P16 confirmed an aversion to interaction through the

FlipMe product when stating, '*I do not care what others do. I have my own watching pattern.'* While for some subject pairs, FlipMe appeared to stimulate more communication than others, across the sample group a statistically significant correlation was identified between handle spin frequency and the number of messages exchanged (Pearson's r = 0.81, Table 4).

Table 4. Spin and message frequencies among participants (N=20)

Participants	Spin frequency	Message frequency
P1 (Assimilator, paired with P2)	0	25
P2 (Assimilator)	9	53
P3 (Diverger, paired with P4)	24	0
P4 (Diverger)	11	0
P5 (Assimilator, paired with P6)	46	49
P6 (Converger)	25	43
P7 (Accommodator, paired with P8)	4	8
P8 (Assimilator)	0	2
P9 (Assimilator, paired with P10)	0	0
P10 (Assimilator)	0	0
P11 (Converger, paired with P12)	0	2
P12 (Diverger,)	2	4
P13 (Assimilator, paired with P14)	97	162
P14 (Accommodator)	58	150
P15 (Diverger, paired with P16)	20	94
P16 (Assimilator)	0	61
P17 (Diverger, paired with P18)	30	8
P18 (Converger)	3	10
P19 (Accomodator, paired with P20)	1	0
P20 (Accomodator)	5	0

This result indicated a significant relation between the use of FlipMe and the number of messages exchanged. However, it is unclear from this result to what extent the paired peers themselves influenced communication and use of FlipMe, as indicated in the differences between pairs illustrated in Figures 15 and 16 above.

To explore the potential influence of differences between paired peers, we examined if learning style may be an influence upon the frequency of handle spins and messaging between pairs (Table 5). The data of group 5 (P9-P10, min), group 7 (P13-14, max) are excluded as outliers. Results indicated the mean (x) value of spin frequency (f) for *Diverger style* learners was highest. Message frequency in the same learning style showed the second highest mean value ($x=21.2$). In contrast, the *Assimilator* recorded the highest mean messaging frequency ($x=38$).

Table 5 Spin and message frequencies by learning styles

Learning styles	Spin frequency (avg.)	Message frequency (avg.)
Divergers	17.4	21.2
Convergers	9.3	18.3
Accomodators	3.3	2.6
Assimilators	11.0	38.0

This initial result may indicate FlipMe's appropriateness for *Diverger* users, described as learners comfortable with exploration and trial in their learning styles. Interestingly P13 was profiled as Assimilator, while P14 was an *Accomodator*. In contrast, P15 was, in fact, classified as *Diverger*, with P16 as *Assimilator*. The two assimilators received the greatest (*f=97*), and least (*f=0*) spin frequency counts. While Table 5 indicates *Assimilators* as making the most use of FlipMe, there was a wide deviation across the sample group. As such, results in the influence of learning style upon communication through FlipMe are inconclusive.

From the above analysis, we tentatively posit three broad insights towards FlipMe's potential to stimulate peer-to-peer interaction during online learning. First, FlipMe did provide an opportunity for interaction, supported by conventional communication platforms (i.e. social media). Second, FlipMe, and its tangible interaction (*spinning handle*), and feedback characteristics (*book-flipping feedback, rolling-ball*) received positive response in terms of the novelty of FlipMe as stimulation for interaction. For example, P8 suggests, *'I realized that my friend was studying. So I wanted to share what I found. I wanted to rush before my friend finished studying before the card stopped flipping'.* Third, a significant correlation between frequencies of handle spins and messaging indicated FlipMe's use coincided with increased use of other forms of communication (i.e. messaging). These findings are further discussed below, together with implications for tangible approaches to product interaction as means to stimulate communication in online learning.

7 Discussion & Conclusions

An initial interview study of experts in and users of online learning platforms derived a set of design requirements aimed at improving communication/collaboration between peers during online learning. These design requirements drove the design, development, and implementation (as a high-fidelity prototype) of FlipMe, an IoT (Internet of Things) product intervention with tangible interaction (rotating handle for nudge feature) and feedback characteristics (flipping book metaphor, rolling ball). An initial pilot study to validate FlipMe's potential indicated the concept's ability to facilitate interaction between peers online, albeit from a user study that is small in scope.

Our pilot validation study indicated FlipMe's ability to provide an opportunity for interaction, supported by conventional communication platforms (i.e. social media). That is, the use of FlipMe appeared to depend upon and be associated with the use of other online means of communication, in particular messaging through social media platforms. However, an identified significant relationship between rotation frequency of FlipMe's handle and messaging across the sample group did not indicate the direction of effect. That is, we cannot say if the increased use of FlipMe resulted in more messaging or vice versa.

The post-session interview did, however, suggest the potential of FlipMe to stimulate learning activity (video watching). For example, *P14* stated in a post-session interview, *'At the beginning of the experiment, I was watching 'YouTube' game clip. But I felt I also needed to study, once I realized my friend was studying.'* Likewise, post-session qualitative responses indicated how FlipMe's use appeared to stimulate interaction suggestive of work-in-progress (video watching). *P13* stated, *'I spun the handle first, then my friend sent a message to ask the reason for spinning. Then we started to chat about the video'.* We interpret these findings as evidence of FlipMe's potential derived from opportunities for tangible, more implicit communication (*flipping book*) to facilitate the explicit communication afforded through text messaging and social applications.

Related to the above, findings also indicated FlipMe's tangible interaction opportunities (*spinning handle*), and feedback characteristics (*book-flipping feedback, rolling-ball*) were positively received by most (but not all) participants. This result indicated FlipMe's value as a catalyst for communication during online learning may depend upon the characteristics of the online learner. An analysis of learning styles through the application of Kolb's (2005) taxonomy was inconclusive in identifying a particular learning type(s) most likely to benefit from FlipMe as means of communication.

Although our pilot validation study has indicated FlipMe's potential as means to facilitate communication in online learning, caution is required in any generalisation or interpretation of these results. First, our initial user study lacks scope in the implementation of the design. From these findings alone, it is not possible to verify the potential of tangible interaction as means to foster increased peer-to-peer communication in online learning. Further studies are required to better account for differences in learning attitudes, styles and expectation as an influence on the appropriateness of FlipMe's tangible approach.

Likewise, to what extent the type of learning material, its content, aim and learning objectives implicated FlipMe's beneficial qualities as stimulation for communication was not measured. Future studies may wish to examine the role of tangible interaction and embodied feedback in relation to different types of learning content (i.e. video, quiz, assignment, audio).

Our initial validation study approximated the geographical dislocation of learners. However, we did not account for time-zone differences, cultural influences or contextual requirements (working at home, in the office, in transit), and so implications for FlipMe's tangible communication approach. Other studies may wish to explore how, for example, changing modes, activities and habits of learning may influence the approach to communication in online learning.

FlipMe's physical flipping feedback approach indicated enhanced engagement in video content. However, future studies may also wish to explore how different types of physical interaction (i.e. press, push, pull) may implicate peer-to-peer communication within the online learning space.

These limitations aside, the current study has indicated tangible interaction has the potential for enhanced communication in online learning. This was achieved through our research through design approach in the design, development, and implementation of the FlipMe concept. Further studies are now required to identify and expand the potential of tangible product interactions to provide more connected learning experiences in the online space.

References

Ahn, J., Weng, C. & Butler. B., S. (2013) The dynamics of open, peer-to-peer learning: what factors influence participation in the P2P University? *System Sciences (HICSS)*, 3098–3107.

Boud, D., Cohen, R. & Sampson, J. (1999) Peer learning and assessment. *Assessment and Evaluation in Higher Education*, 24(4): 413–426.

Brave, S. & Dahley. A. (1997) inTouch: A Medium for Haptic Interpersonal Communication. *In* CHI '97 Extended Abstracts on Human Factors in Computing Systems *(CHI EA '97)*. ACM, New York, NY, USA, 363-364. DOI: https://doi.org/10.1145/1120212.1120435

Cercone, K. (2008) Characteristics of Adult Learners With Implications for Online Learning Design. *AACE Journal*, 16(2): 137-159.

Coursera Inc. (2019) Accessed 11.04.19. https://www.coursera.org/

Gaver, W. W., Bowers, J., Boehner, K., Boucher, A., Cameron, D. W., Hauenstein, M., & Pennington, S. (2013) Indoor weather stations: investigating a ludic approach to environmental HCI through batch prototyping. *In Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, 3451-3460.

Ishii, H., Wisneski, C., Brave, S., Dahley, A., Gorbet, M., Ullmer, B. and Yarin, P. (1998) ambientROOM: integrating ambient media with architectural space. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '98)*, 173-174. http://doi.acm.org/10.1145/286498.286652

Jansen, Y., Dragicevic, P., Isenberg, P., Alexander, J., Karnik, A., Kildal, J., Subramanian, S. & Kasper H. (2016) Opportunities and Challenges for Data Physicalization. *Proceedings of the 2015 annual conference on Human factors in computing systems (CHI'15)*. 3227-3236.

Johnson, M (1987) *The body in the mind: The bodily basis of meaning, imagination, and reason*. Chicago, IL, US: University of Chicago Press.

Jones, S. E., & Yarbrough, A. E. (1985). A naturalistic study of the meanings of touch. *Communications Monographs*, 52(1), 19-56.

Khan Academy (2019) Accessed 11.04.19. https://www.khanacademy.org/

Kim, T., Park, Y., W., Hong, H. (2017) Calm Station: An Interactive Perpetual Desk Object that Reduces Digital Distractions. *DIS'17 Demo*, ACM Press, Edinburgh, UK, June 10-14.

Kolb, A. Y. (2005) The Kolb learning style inventory-version 3.1, *2005 technical specifications*. Boston, MA: Hay Resource Direct, 200, 72.

Locke, E.A. & Latham, G.P. (2002) Building a Practically Useful Theory of Goal Setting and Task Motivation: A 35-Year Odyssey," *Amer Psych*, 57(9): 705-17.

Lu, H., Jia, L., Gong, S.H., & Clark, B. (2007) The Relationship of Kolb Learning Styles, Online Learning Behaviors and Learning Outcomes. *Educational Technology & Society*, 10 (4): 187-196.

Neese, B. (2016) Different Learning Styles and Effective Communication. *Husson University Online*. Accessed, 11.04.19, https://online.husson.edu/different-learning-styles/

Nisbet, D. (2004) Measuring the quantity and quality of online discussion group interaction. *Journal of eLiteracy*, 1(2): 122-139.

Norman, D., Simsarian, K. & Glasson, C (2019) Lesson 1: Affordance and Signifiers. Intro to the Design of Everyday things, *Udacity Inc*. New York, USA. Accessed 11.04.19,https://www.udacity.com/course/intro-to-the-design-of-everyday-things--design101

O'Donnell, A. M., & King, A. (1999) The Rutgers Invitational Symposium On Education Series. *Cognitive perspectives on Peer Learning*. (Eds.).Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Pope, J. (2015) What are MOOCs good for? *Technology Review*, 118(1): 69–71.

Sauvé, K., Houben, S., Marquardt, N., Bakker, S., Hengeveld, B., Gallacher, S., & Rogers, Y. (2017) LOOP: A Physical Artifact to Facilitate Seamless Interaction with Personal Data in Everyday Life. *In* Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems *(DIS '17 Companion)*. ACM, New York, NY, USA, 285-288. DOI: https://doi.org/10.1145/3064857.3079175

Shah. D. (2017) A Product at Every Price: A Review of MOOC Stats and Trends in 2017. In Class Central Mooc report, *Class Central*. Accessed 11.04.2019. https://www.classcentral.com/report/moocs-stats-and-trends-2017/

Strong, R., & Gaver, W., W. (1996). Feather, scent, and shaker: Supporting simple intimacy. *Proceedings of CSCW'96,* Nov. 16 - 20, Boston, USA.

Thomas, L. (2002) Student retention in higher education: The role of institutional habitus, *Journal of Education Policy*, 17(4): 423–442. doi: 10.1080/02680930210140257

Udacity. Inc. (2019). Accessed 11.04.19. https://www.udacity.com/

Zhao, J. & Vande Moere., A. (2008) Embodiment in Data Sculpture: A Model of the Physical Visualization of Information. *Proceedings of the Third International Conference on Digital Interactive Media in Entertainment and Arts, DIMEA 2008*, 10-12 September 2008, Athens, Greece.

Casakin, Hernan. (2007). Metaphors in Design Problem-Solving: Implications for Creativity. International Journal of Design. 1. 23-35.

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