# An Implementation of Tangible Interactive Mapping to Improve Adult Learning for Preparing for Bushfire

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## ABSTRACT
Our tangible touch table interface mapping system was designed for adults to complete short map-based interactive problem solving tasks using purpose-designed model objects. The table interface was compared with the closest existing traditionally equivalent method using a within subjects exercise of 64 adult members of the general public in-situ at the local library and museum.

The hypothesis investigated whether "a tangible multi-touch table interface improved understanding of preparing for bushfire using map-based constructivist learning tasks". The system design and content founded upon adult learning preferences (Knowles et al. 2005) further evolved using an iterative process by participatory involvement with three bushfire community groups.

After using the *preparing for bushfire* tangible interactive mapping system all of the participants improved upon their pre-test scores indicating that they learned from the experience ($t(31)=-9.08, p<0.001$).

### Author Keywords
Interaction Design; Tangible, Multi-touch table.

### ACM Classification Keywords
H5.2 User Interfaces: Evaluation/methodology.

## INTRODUCTION
Bushfire is currently a greater problem in Australia than ever before. Yet despite this risk, few residents regularly prepare for the bushfire season (Mackie et al., 2013). Promoting *preparing for bushfire* is an ongoing priority for fire agencies, who actively apply a wide range of methods to raise awareness to the general public. However existing methods do not seem to be getting the message across hence new technology may offer a solution to improve understanding to inspire and motivate action.

Our target audience was adult members of the general public therefore our study applied adult learning theory (Andragogy) incorporating its six core principles (Knowles et al. 2005). These learning principles were employed using: constructivist learning theory being the most relevant to this study as a learner focused theory rather than subject focused (Ormrod 2004).



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Our research strategy for this study was to investigate use of touch table technology which offers an opportunity to present bushfire education messages in a practical appealing manner while minimizing misconceptions.

A comprehensive literature review within this study, combined with the spatial nature of bushfire spread and the preferred learning mechanisms for adults, indicated that an interactive map-based tangible touch table system using constructivist learning tasks could suit our research goal.

We designed a set of three scaffolded interactive local real-world map examples and exercise tasks specifically to appeal to adult learning preferences. Similarly the tangible interface objects were designed to draw attention focus and appeal to adult users.

Our study analyses learning gains from using our system compared with the closest traditionally available alternative. We applied a contributing factors analysis that quantified the impact of the tangible interface objects to the improvement in test scores.

The results suggest that adults learnt more about preparing for bushfire from our tangible interactive map system than from traditional methods ($F(1)=13.01, p<0.001$).

This work appeals to aspects of adult learning, tangible user interface design, and techniques for engaging with the general public.

## RELATED WORK
Although many empirical studies compare tangible user interfaces (TUI) to other systems. Few empirical studies in Tangible User Interface (TUI) research focus both on adults and tangible multi-touch tables (Antle & Wise 2013).

The following studies are the closest to our *preparing for bushfire* exercise (Kirk et al. 2009; Schneider et al. 2013; Speelpenning et al. 2011).

The early Kirk et al. (2009) study reviewed design decisions for what they called hybrid systems – "interactive systems combining techniques of direct-manipulation multi-touch surface interaction with elements of tangible user interfaces (TUIs)" (Kirk et al. 2009, p.35). The study focused upon the issue of decision rules to determine if interface elements should be a physical or digital instance. The study compared two hybrid applications justifying decision rules for virtual and tangible controls. Kirk et al. (2009) proposed a set of design considerations which included account representation, affordance, physical function, and feedback.

The Speelpenning et al. (2011) study extended the multi-touch Futura game to include a tangible interface tool. The tool showed extra information on the impact of player actions. The study compared the effect on collaborative activity of the tangible tool against a virtual equivalent. Qualitative results showed that the collaborative activity was more related to group dynamics than tool use. However they noted that some individuals tended to take ownership of the tangible tool which supported awareness and group focus.

The closest to our method is from Schneider et al (2013) who investigated the capability of a multi-touch table tangible interface of a neurological simulation to teach adult students fundamentals of neuroscience. Their within subjects exercise used 28 graduate students in groups. They compared a TUI to reading from a text book. Their TUI was a model of neurological pathways of the visual system of the brain using model sections of the brain. The students used freeform exploration to create rules to explain how visual information is processed in the brain. The students spent 15 minutes on each condition. The experiment achieved positive learning outcomes from using the TUI in conjunction with the textbook regardless of order. These outcomes were attributed to the design of the TUI implemented in a Future Learning Framework.

## SYSTEM DESIGN

*Preparing for bushfire* is primarily concerned with reducing available fire fuels (leaves, branches, and trees) from within a dual buffer zone around the home. The inner buffer zone closest to the house is typically 10m, while the outer zone is typically 25m. The distances vary depending on steepness of terrain.

The touch table interface used a Microsoft PixelSense which displayed local real world map information including online aerial photographs, property boundaries, building locations, elevation, fire history, and fire defensive zones. Three tangible objects (house, rake and chainsaw) were selected as physical rather than virtual controls. Consequently our PixelSense interface system was designed for adults to complete short map-based interactive bushfire problem solving tasks using purpose-designed model objects: including the house, chainsaw and a rake (Figure 1).

Our interactive interface was controlled by touch buttons, tangible model object interaction and by finger touch gestures. All map controls were standard smart phone gestures.

Objects were designed to be sufficiently realistic so they would be easily associated with their purpose (Brown et al. 2014). The object size was designed as a balance between being large enough to be functional while minimising the occlusion of visual information on the display.

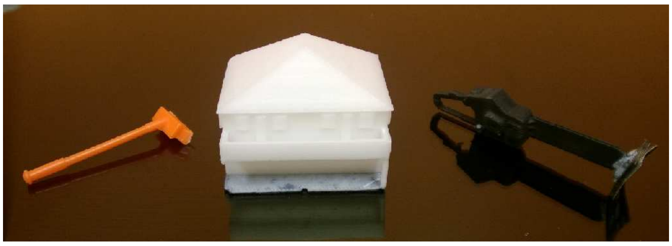

**Figure 1: The interface tangible objects.**

The house was chosen as a tangible model object because residents attach a large sentimental value to their home, furthermore a house was the primary focus of *preparing for bushfire*, therefore it draws attention of those using the interface. The defensive zones were measured from around the house so the house object was given the function to display the defensive zones when placed upon the table (as seen as dashed lines in Figure 2). The design of the house was chosen from several styles to be representative.

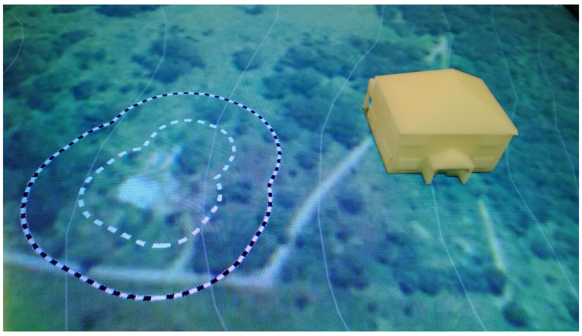

**Figure 2: The house interface object placed upon the surface turns on the buffer zone lines of the defensive zones on the airphoto shown as white dashed lines.**

The rake and chainsaw tools were used to depict clearing of bushfire fuel in the defensive zones by displaying immediate interactive feedback as graphical changes overwriting the on-screen airphotos. These tangible tools operated using actions as they would in the real world. The rake swept thus was operated by placing the rake head on the photo image and sweeping. Similarly the chainsaw used a cutting action. It takes several attempts to cut vegetation thus the chainsaw cutting action was applied in a series of cutting gestures. It was quick and efficient.

The tangible model tools have a tight metaphor between their physical design and purpose because their high fidelity and function was easily interpreted as a way of visualising an operation (Marshall (2007). Visualisation of the experience is aided by the tangible tools.

## METHOD

The table interface was compared with the closest existing traditionally equivalent method using a within subjects exercise of 64 adult members of the general public in-situ at the local library and museum. This study followed a similar format as other TUI comparative evaluations (Price & Falco 2011; Speelpenning et al. 2011; Schneider et al. 2013)

The closest traditionally available alternative was paper maps which perform an equivalent function as the interactive mapping table albeit without the zoom and pan ability.

An earlier extensive pilot study showed the general public was not interested in using alternate systems when the touch table was available, therefore the paper maps were substituted with static digital maps displayed on the touch table. In conjunction novelty avoidance was designed, tested and introduced prior to beginning of the exercise.

In order to maximise the exposure to the general public the exercise was deployed in the main regional library and the city museum, because these locations were perceived as popular commonly used public spaces. More importantly, visitors to these sites were thought likely to both be adults and have spare time. The exercise was publicised on ABC radio, via flyers, and posters on the bulletin boards around the library.

### The Comparative Study Design

The comparative study used a within subjects design comparing the tangible interface to the static maps (Figure 3). The advantage of using a within subjects design was that all individuals and groups used both systems, therefore participants were in a position to compare the two systems (Sauro & Lewis 2012).

Initially all participants completed a pre-test, which measured their level of knowledge of *preparing for bushfire*. After which, participants watched a 4min 30sec official State Fire Service *preparing your house for bushfire* training video. This action ensured every participant received identical information delivered in an identical manner.

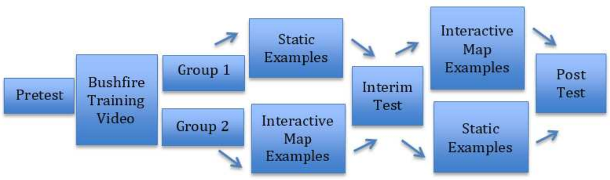


**Figure 3: The within subjects design for the evaluation.**

The participants were then separated into two groups, according to a pre-prepared random stratified list. One group started with traditional methods (static map), while the other group started with the tangible interactive map. Members completed a structured scaffolded set of worked examples. After which all participants were tested with a written and practical test to measure their knowledge of *preparing for bushfire* at this interim stage. The practical test was a structured set of scenarios similar to the worked examples. The level of comprehension was measured by quantitative methods to test recall of facts and application of theory by active processes (Fink, 2003). The groups then swapped over to the other system where they completed another set of worked examples, followed by another scored written test and practical test set of scenarios.

At the end of the exercise participants completed a detailed review questionnaire about their experience. The questionnaire included questions concerning existence of indicators for learning (Knowles et al. 2005). Some questions were based on those used in similar peer reviewed constructivist comparisons (Ryan & Deci 2000).

### Novelty Avoidance

In order to reduce the novelty factor (Ott & Luderschmidt 2012) each participant was allowed to use the touch table prior to the experiment. This five minute play period introduced all the features of multi-touch as-well as the concept of using a tangible interface object. The length and style of the session was based upon personal observations of hundreds of users from public demonstrations.

### Participants

The participant group consisted of 64 adults of the general public (26 Female and 38 Male) aged between 18 and 82. The participants considered themselves very familiar with touch and gesture.

## RESULTS AND DISCUSSION

### Evidence of Learning

A learning gain occurs if a positive significant difference occurs between test scores in successive tests (Sauro & Lewis 2012). A paired-t test determines statistical significance between successive tests. Learning gains potentially occur between each of the tests, therefore three paired-t tests were conducted in SPSS for both starting cases:

1. Pre-test and final post-test,
2. Pre-test and interim test and
3. Interim test and final post-test.

In the case starting with the traditional method (static map) followed by the tangible interactive map table, the learning gains were statistically significant for all three conditions ($p< 0.001$) (shown by the red line in Figure 4).

In the case starting with the tangible interactive map table followed by the traditional method (static map), the test scores were statistically significant for initial learning (pre-test – interim test)($t(31)=-9.86, p<0.001$) and overall learning (pre-test – post-test)($t(31)=-9.08, p<0.001$). However there was no new learning gain for the second stage (interim test– post-test). This is observed by the blue line in Figure 4 with the large initial increase then the flat line to the post-test (same score – no increase).

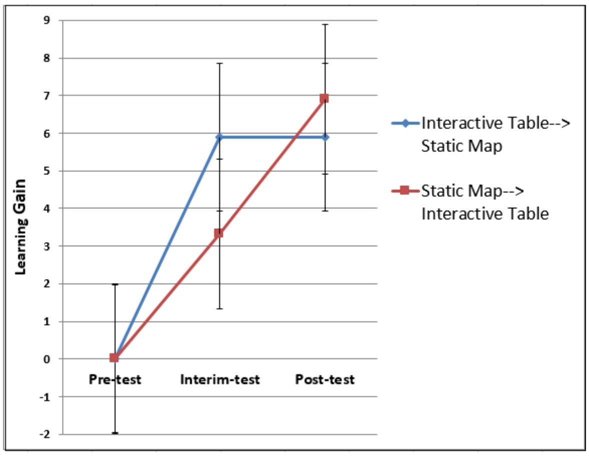


**Figure 4: Learning gains between the tests.**

Greater pre-test to interim test learning gains occurred using the interactive map table compared to static map ($F(1)=13.01, p<0.001$).

Similarly, greater second stage (interim test to post-test) learning gains occurred using the interactive map table compared to static map ($F(1)=33.93, p<0.0001$).

In summary, the significant learning gain outcomes are:

- Learning gain from the tangible interactive map table session alone is equivalent to the overall gain of the two stage learning from using traditional (static map) followed by interactive map table ($F(1)=13.01, p<0.001$) (Figure 4), and
- Tangible interactive map table sessions provided statistically significant learning gains whether used first or second ($p<0.001$).

A breakdown of contributing factors was calculated using a multiple regression analysis. It showed that the number of times interface objects (house, rake and chainsaw) were used within the interface was significantly correlated to the learning gain ($t(29)=2.37, p<0.01$). This result indicates that using objects aided in learning. Similarly the time on task was significantly correlated to the learning gain ($t(29) = 5.23$, $p < .001$). The correlation to time on task is not surprising as it is a known contributor to learning.

The significant contributing factor of the tangible objects along with the positive learning gain from the interactive map table support our hypothesis.

## LIMITATIONS

The most contentious limitation was that interface objects may have acted as prompts. Their presence may have reminded the participant of actions they needed to perform during the scored practical exercises. A similar problem was noted by Schneider et al. (2013) where they suggest using identical instructions for each group. This suggestion was implemented within our configuration of the exercise.

## CONCLUSIONS

Our study provided empirical evidence from our sample group of 64 adult members of the general public that they improved their understanding of *preparing for bushfire* by using our purpose designed tangible multi-touch table system ($t(31)=-9.08, p<0.001$). Custom physical models and time spent using map-based constructivist learning tasks were found to directly correlate to the learning improvement ($t(29)=2.37, p<0.01$).

Adults were found to learn as much from using the tangible interactive mapping system by itself than from using a two stage learning process of the traditional method (static map) followed by the tangible interactive table ($F(1)=13.01, p<0.001$).

In future research we aim to explore the contribution of objects to the learning gain.

## ACKNOWLEDGEMENTS

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