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Exploring Distributed Cognition Collaborative Group Learning on Interactive Tabletop Displays

Master of Science Thesis in the Programme Interaction Design

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Göteborg, Sweden, April 2012

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The cover image is a screenshot of the digital Icebreaker module found at the beginning of the second design iteration in the report.

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1 Abstract

Learning and education are research fields with a myriad of different theories, frameworks and methods. They cover everything from the traditional classroom session to how the population of a whole country learns over decades. One specific type of learning is how a small group of people sitting around a table solving problems learn from each other and the material at hand. This type of learning is often modeled as Distributed Cognition learning.

Specifique AS develops a type of paper tool that fits right into the Distributed Cognition category of learning and has been working on it for over 20 years. Their wish is to re-imagine this tool in digital form to improve its function. Taking analog tools and improving them by making them digital has a very successful history, and making this specific kind of learning digital is a relatively unexplored field. It is just now that this kind of technology is cheap enough and readily available to make it feasible for a bigger market. There is a clear opportunity to break new ground.

Touchtech AB is a Gothenburg based company that focuses on multi-touch and other NUI solutions to various problems. Utilizing their and Specifique's knowledge in their respective fields the goal of this thesis is to take a step in the direction of how to design a new tabletop display based DC learning tool. The method used is a variation of a Goal Directed design method. Starting with scope definition, stakeholder interviews, audit of existing work, user observations, design phase and user tests. This was conducted in two iterations.

The final results of the thesis are a set of key design considerations for designing tabletop display DC learning tools. Because of the thesis' limited scope it is difficult to draw any general conclusions on the benefit of using a digital tool instead of an analog one, but the results seem to indicate that using a digital tabletop display instead of a analog has clear benefits. Mainly by giving designers more tools in their toolbox to shape the user experience. The design considerations in this thesis is a list of guidelines that help designers use those tools in the right way to facilitate DC learning.

2 Table of contents

3 List of abbreviations

These are the abbreviations that are being used in this report.

BM	Business Mat
CSCL	Computer Supported Collaborative Learning
DC	Distributed Cognition
GUI	Graphical User Interface
NUI	Natural User Interface

4 Acknowledgements

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The eight people that participated in the user tests at Touchtech, the tests provided the most valuable feedback of all.

5 Introduction

Learning and education are research fields with a myriad of different theories, frameworks and methods. They cover everything from the traditional classroom session to how the population of a whole country learns over decades.

The topic for this thesis is about how a small group of people sitting around a table, supported by technology, can learn collaboratively from each other and the material at hand. This type of learning is often modeled as Distributed Cognition learning, and that is the framework the learning part of this thesis is based on.

The purpose of this thesis is to explore and investigate how a interactive tabletop display, or multi-touch table can act as support for small group learning sessions. Using multi-touch tables as support for learning is a relatively unexplored field, at least commercially, and there is a clear opportunity to break new ground.

The original idea for this thesis comes from the wish to convert an existing analog learning concept called a *Business Mat* (Specifique AS, n.d.) into a computer supported version. The business mat is a trademarked commercial product developed by Norwegian company Specifique and has been their main product for over 20 years.

The basis for the work method used in this thesis is part of a goal-directed design process with two iterations. (Cooper et al., 2007) We start by researching existing work, perform user observations and stakeholder interviews. Elicit user needs and translate into design requirements. Then we design and implement a number of prototypes that explore different aspects of the problem. Using these prototypes we perform user tests, followed by another design phase. At the end a final user test is performed.

Interaction Design is not an exact science, but it is still important to strive towards the scientific method when performing tests and observing users. Since this thesis had quite limited scope for the user tests, it is difficult to draw any definitive general conclusions from the results. However, the qualitative analysis points in a direction that indicates that multi-touch tables have great possibility to guide a group in the right direction towards a good learning outcome, much more so than paper or other passive support tools.

6 Literature review

6.1 Distributed Cognition in learning

The theory of distributed cognition, like any cognitive theory, seeks to understand the organization of cognitive systems (Hollan et al., 2000). Traditional cognition system focus on person's internal cognition and external environment which include all kinds of material like computers, books, etc. From a learning's point of view, the traditional method did not consider multiple people and learning materials as a whole unit. On the other hand Distributed Cognition is an approach which considers the power of collaboration. It focus on information flow which is created from interaction between people and artifacts.

There are two principles that distinguish DC from other cognitive approaches. (Hollan et al., 2000)

1. The boundaries of the unit of analysis for cognition. Cognitive process is delimited by the functional relationships among the elements that participate in it, rather than by individuals as in traditional cognition theory. "The resources in the world are used, or come together in use, to shape and direct possible activity." (D.Pea, 1997)

   Hollan et al. suggest three kinds of distribution of cognitive process become apparent:

   a. Cognitive processes may be distributed across the members of a social group.
   b. Cognitive processes may involve coordination between internal and external (material or environmental) structure.
   c. Processes may be distributed through time in such a way that the products of earlier events can transform the nature of later events.

2. Distributed Cognition concerns the range of mechanisms that partake in the cognitive system. (e.g. interplay between human memory, external representations and the manipulation of objects). From traditional cognition's point of view, each symbol inside of the individual mind play an important role in the human's memory. Whereas, DC expends memory mechanism to interaction between internal process, the manipulation of objects and the representations of external resources.

In all as a theory framework DC suggests that we focus on the information flow between members of the group, coordination between personal internal and external structure, and how products of earlier events can transform the nature of later events.

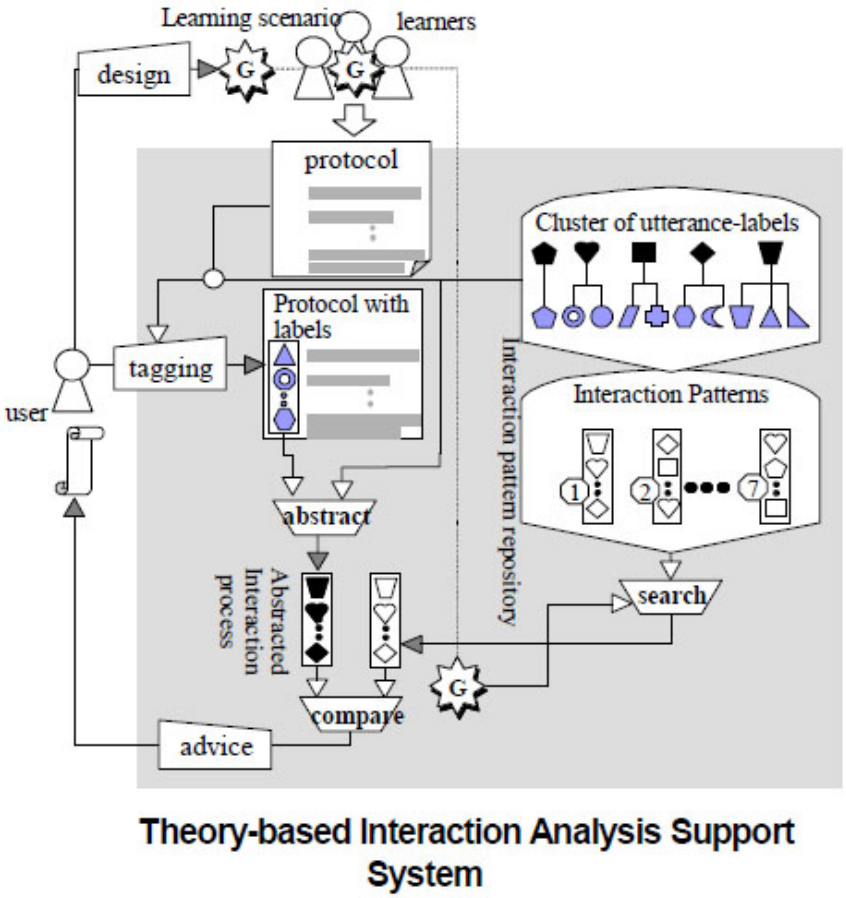
6.2 Evaluation of DC learning

How do you evaluate a learning session? Can DC learning be as easily evaluated as other kinds of leaning? For example, would it be possible to use traditional exams to test how much the

participants learned? To be able to figure out how to evaluate DC learning, an investigation on collaborative learning needs to be performed first. Pierre Dillenbourg has analyzed Collaborative learning from three aspects: (Dillenbourg, 1999)

- The variety of scales: from 2 to 30 subjects, from 20 minutes to one year.
- The variety of meanings for “Learning”: pedagogical method or psychological process?
- The variety of meanings for “Collaboration”: situation, interactions or learning mechanisms?

Following up on Dillenbourg's work, Akiko Inaba categorized collaborative learning into seven types: peer tutoring, cognitive apprenticeship, anchored instruction, cognitive constructivism, distributed cognition cognitive flexibility and lpp. (Inaba et al., 2003). At the same time, Inaba et al. also designed an interaction analysis support system.

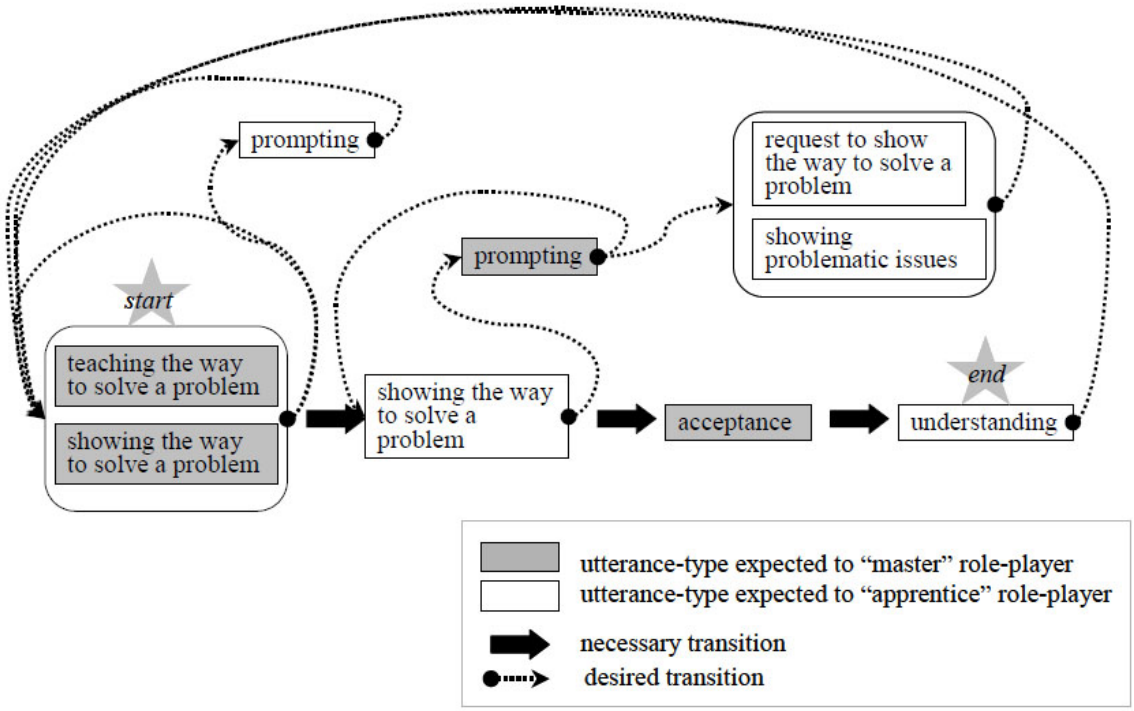


Theory-based Interaction Analysis Support System

Figure 1

Based on Inaba et al’s theory, this system works on all kinds of collaborative learning including DC learning. The system is pretty easy to understand: first collect a protocol which is raw data on all words and sentences said by participants. Then, tag the protocol data into predefined utterance types. For example, an utterance from a user test in this thesis: “Because she thinks it is important to connect to people ”, could be tagged as a “showing a way to solve a problem”. And the utterance “I don't think it's a kind of emotional, yeah, it's logic” could be tagged as Arguing one’s opinions, etc.

After all utterances have been labeled, an interaction pattern can be produced. The diagram below is an example of Cognitive apprenticeship learning. (Inaba et al., 2002)



An example of Interaction Pattern: cognitive apprenticeship

Figure 2

As the final step, compare the interaction pattern with another "ideal" pattern which was previously specified based on the learning goals before collaborative learning happens. For example the ideal pattern could have users prompting each other and going into detail in the discussion.

We believe for other collaborative learning scenarios such as peer tutoring and cognitive apprenticeship, it is easier to draw an ideal interaction pattern. Usually there is one teacher and one student, and you know what to expect from each role. On the other hand, for four people having a distributed cognition learning session where they all talk over each other and no pre-fixed structure exists, in comparison it is difficult to draw the ideal interaction pattern. However, this method theoretically works in our case so utterance analysis will be attempted in this study.

6.3 Guidelines for tabletop display

For interactive tabletop display design, there are existing studies on Co-located and Collaborative tabletop design. Here we list some important proven guidelines from D. Scott (Scott et al., 2003) and M. Morris (Morris & Winograd, 2004)

- Support interpersonal interaction
- Parallel input has been found to decrease the opportunity for one user to dominate while on the other hand it has been found to result in decreased quality of discussion. (Marshall et al., 2008)

- Equity of physical participation does not influence user's perception of overall equity, verbal participation however does:

  "Findings for interaction equity were however not echoed in the findings for verbal participation or for overall perception of effective group working, where no differences were found across conditions. This would appear to suggest that participants' perceptions of effective group working are influenced primarily by the nature of the verbal discussion rather than equity in interacting with the interface." (Marshall et al., 2008)

- Support fluid transitions between activities
- Support transitions between personal and group work
- Support transitions between tabletop collaboration and external work
- Support the use of physical objects
- Provide shared access to physical and digital objects
- Consideration for the appropriate arrangements of users
- Support simultaneous user actions
- Consider the location of interactions
- Consider distribution of actions among group members
- Consider the number of people that handle each object
- Orientation of short phases does not hinder people's reading. (Wigdor et al., 2005)

There exist many more useful guidelines and we would recommend the book Tabletops - Horizontal Interactive Displays (Müller-Tomfelde, 2010) for more reading.

6.4 Inequality Index

$$I = \frac{\frac{1}{N}\sum_{i=1}^{N}(E_i - O_i)}{\frac{1}{2}\left(1 - \frac{1}{N}\right)}$$

Equation 1

Specifique has as a goal that all participants should participate equally in the business mat. We also noticed in the pre-study that some participants do not do this, and seem to learn a lot less. For these reasons we defined equality of participation as a design goal, and it becomes important to measure the equality of participation in the user tests. A method called Inequality Index (Hiltz et al., 1989) is used for this. It is calculated as stated in Equation 1.

- N = number of participants in the group
- E_i = expected cumulative proportion of words if all contribute equally

- O_i = observed cumulative proportion starting with the least active group member.
- The resulting number I is an index from 0 (total equality) to 1 (a monologue).

This gives us a way of comparing individual modules, the paper mat and the digital modules. This is done by transcribing the recorded video and counting the number of spoken words for each participant. Then feeding that data into the model and ending up with a number that indicates the equality.

7 Technical Description

7.1 Business Mat

"Business Mat" (BM) is a trademarked term and a product of Specifique AS (Specifique AS, n.d.); it is an example of a distributed cognition tool for DC learning. Here follows a description of its features and function.

Specifique produce many kinds of Business Mats and all of them are designed for a small group of people to use. Even though Specifique tailors each business mat to teach a specific subject, there are many common features in all mats.

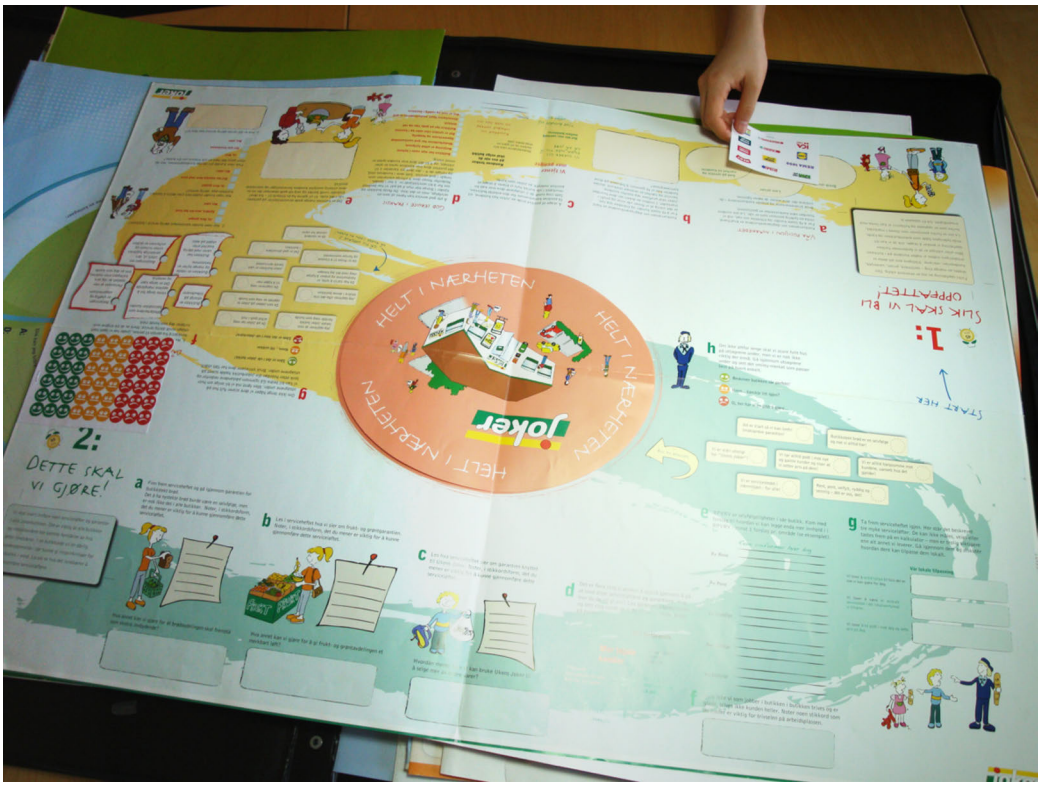


Figure 3

A Business Mat (Figure 3) is usually a sheet of A1 paper, with content tailored for a target group. Four persons sit around it, two on each side. The group then progress together through the guided process for about 2-3 hours. The goal of all mats is to let people learn from each other, and from the mat, based on the theme of the mat. They go through the whole mat together step by step, solving problems and answering questions, by following instructions. There are no right or wrong answers, as long as the group agrees on an answer it is valid.

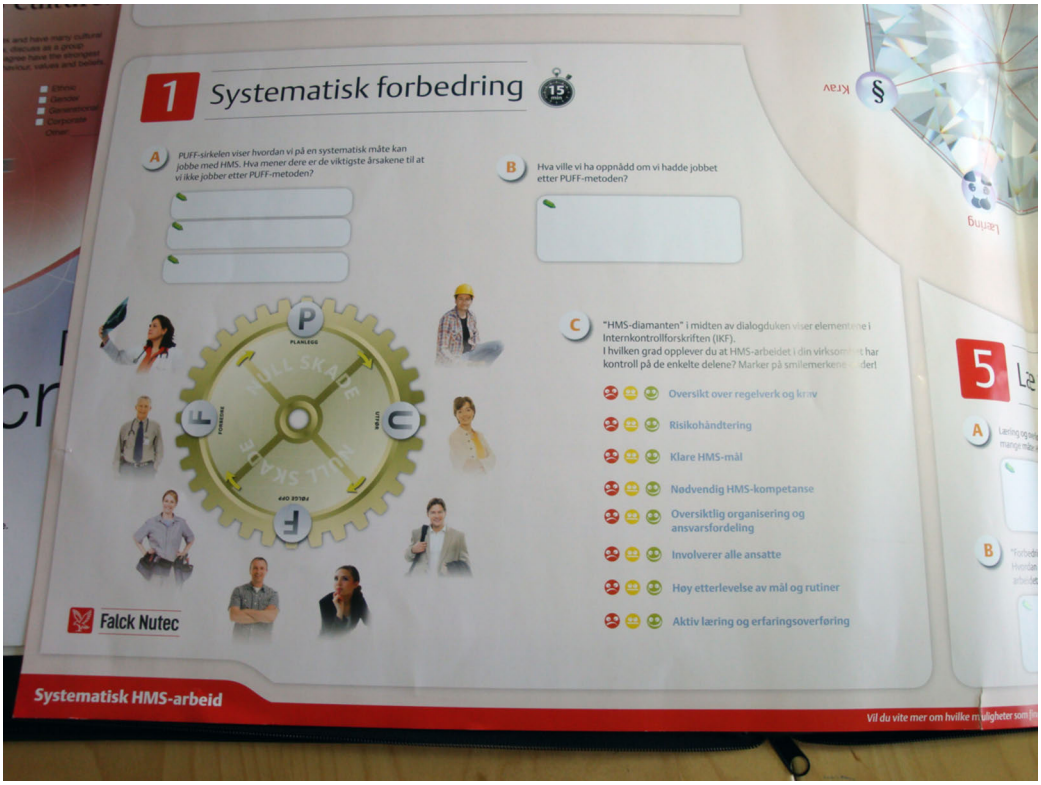


Figure 4

A Business Mat is usually divided into sections, or modules (Figure 4). By having each person in charge of modules close to them, the intention is to activate everyone, encouraging them to talk and take part. Each module have time limitations stated next to them, both to limit the time spent on the module, but also to indicate how much time the group should spend on that module.

Designers at Specifique believe, based on their experience, that equity of participation is one of the most important aspects of efficient DC learning. Therefore having everyone participate equally is one of their main design goals. There are some studies that have been done on equity of group participation. When it comes to group participation on tabletop interface design, two equities are defined: *physical interaction participation* and *verbal participation*. (Marshall et al., 2008) Based on their importance in existing business mats and what we saw during the pre-study, these two equities are design goals for the entire process. Even though they seem similar they are actually very loosely coupled. The degree of physical participation has very little influence on verbal participation. (Marshall et al., 2008)

7.2 Microsoft Surface 2

Figure 5

When it comes to choosing hardware, we considered digital tablets, smartphones and Microsoft Surface 1 and 2. To be able to pick the best one for our case, there were some aspects we needed to consider: From learning's point of view, the hardware should be able to focus users on the same task and evoke discussion; from technology's point of view, high quality hardware (resolution, sensors) and strong software framework support are essential. We would like to focus on implementing software prototypes, not fiddle with hardware or writing frameworks. In addition, final use environment should also be a part of consideration. Therefore, we chose Microsoft Surface 2 (Figure 5). Based on the goal of this thesis, time and financial limitations, Microsoft Surface 2 was chosen at the beginning of the thesis.

As the picture above shows, Microsoft Surface2 is a 40 inch full HD screen, 4 inches thick table embedded with a computer. It supports more than 50 simultaneous inputs and tangible objects. The Surface solution also includes a framework called Windows Presentation Foundation that help make the implementation much easier. Microsoft provides specific tabletop libraries for Surface 2 as well. For example: scatterview and scatterviewitems which allow you to drag items with tailored content around on the table.

8 Research questions

In order to limit the scope and get useful results form this exploratory thesis, the following two research questions were defined:

- What are key design considerations when making a tabletop display, short timespan, Distributed Cognition learning tool?
- Does using a digital tabletop display instead of analog tools to support the interaction between users, and between users and external material, benefit or harm Distributed Cognition learning?

We attempt to answer both of these questions throughout the results and conclusion parts.

9 Study

9.1 Goal-Directed Design Process

The foundation for the design process of this thesis comes from the goal-directed design method specified in About Face (Cooper et al., 2007). It emphasizes the end goals of users and stakeholders, rather than focusing on the features and functions. It makes sense for this thesis since we are trying to explore new ground. Previous solutions to these problems are useful as inspiration and in understanding different approaches to reaching end goals. But it doesn't make sense to analyze tasks in detail since the goal isn't a slight redesign, but rather an exploration and evaluation of new possibilities.

We use the first part of the goal directed process since this thesis is about research and investigation rather than having an end product.

9.2 Pre-Study

9.2.1 Scope & Stakeholder interviews

The goal directed process starts with defining the scope, i.e. project goals and schedule. The reason for starting here is obvious; these are the main limitations for the work and needs to be considered in all future phases.

For this thesis the work is to be completed within the scope of a 30p Master Thesis. Touchtech and Specifique are able to provide technical and domain knowledge, access to hardware and financial support for various things, like travel expenditures or compensation to users for user tests.

When it comes to project goals they became clear after the Stakeholder interviews, which About Face suggests are done as early as possible (Cooper et al., 2007). In this project there are two main stakeholders: Touchtech AB and Specifique AS. After meetings and interviews with both it became clear that they had overlapping goals which boiled down to: conduct research that will be useful in future product development of technology supported group e-learning tools.

During these meetings we also identified the customer and target users. The customers Specifique currently have for the existing analog tool are organizations that want to provide tailored structured education for their employees, or other professionals connected to their organization. The target users are employees who participate in education workshops where the existing business mats are being used. So we continued with this group of people as target users as it seemed like the most feasible target group for any future product; it also allow us to observe the intended users when using the existing tool. In order to do that we needed a case, someone who is actively using a Business Mat. Specifique facilitated contact with the company Aker Solutions who is using one of the existing business mats to perform cross-culture education. With a case like this we had access both to a customer and users to interview and observe; a cornerstone of the goal-directed process.

Besides Touchtech and Specifique, customer interviews were also conducted. We had meetings with Aker Solution's Cross-culture expert and HR manager where we found out that they are very interested in developing a virtual learning tool which can support people from different locations to learn together. After thorough analysis, we decided to not to go for this customer's goal because of a huge amount of work on implementation, lost focus on Interaction Design, difficulty of test and implementation. Usually a project's goal is to satisfy the customers, but in our case, a master thesis has many goals, to satisfy final customer (Aker Solutions) is one, but a major constraint is having to finish the thesis within its scope.

9.2.2 Audit

The audit part of the goal-directed process was performed after the stakeholder interviews. The project goals had to be defined before we could start investigating previous work.

Apart from general interaction design principles, we had to acquire knowledge in two areas specific to this project: tabletop interface design and learning theories.

Design for multi-touch tabletop displays has its own set of principles and guidelines, quite different from regular GUI design. We read books, papers and consulted with Touchtech regarding these issues. See the Literature Review section for a full set of considerations.

When it comes to learning we got knowledge from Specifique who has been in this business for a long time, but we also studied books and papers. There were two big reasons for delving deeper into learning theories: First we need to know what constitutes good learning, what things are important for learning and what frameworks exist. This is important when observing and interviewing users, it allows us to ask relevant questions and keep an eye out for important observations. Secondly, we know how to evaluate systems when it comes to Interaction Design. For example testing the efficiency or usability; since learning is the main goal here, knowing how to evaluate for that is very important.

At this stage, we identified this type of group learning as Distributed Cognition learning and found a method to analyze and evaluate a DC learning sessions. Details are listed in previous Literature review section.

9.2.3 User Observations & Interviews

Initially two user observations were conducted, both with Specifique's client Aker Solutions at their offices in Oslo. One observation was of a PDF version of the mat which was used by split location groups in different countries over the Internet, and one of them was the actual paper version business mat. Besides user observations, interviews with target users were also made. As we mentioned previously, the final customer would like the thesis to help them with education in separate location, but we did not go down that path. However, we still conducted the observation of split location PDF mats in hopes that it would provide insight into how technology can support this kind of group learning.

9.2.4 User Study PDF Mat

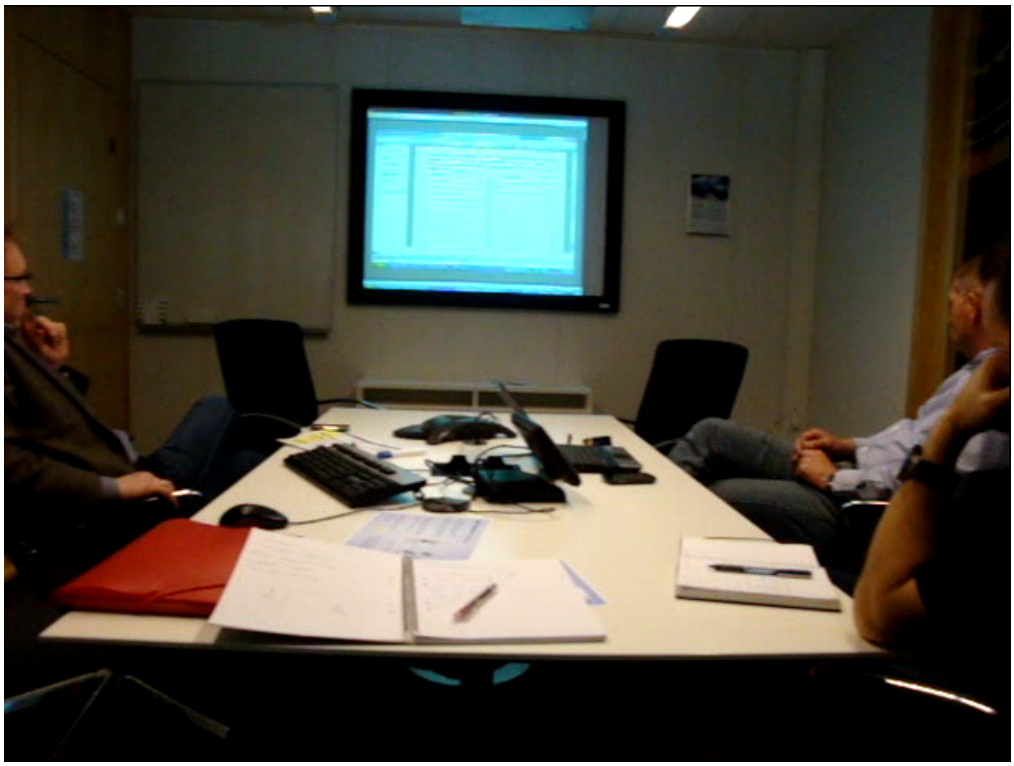


Figure 6

9.2.4.1 Method

This observation was conducted at Aker Solutions Oslo offices (Figure 6). The users were taking part in a cross culture course with a split location theme. The course had around 30 participants and they were split into groups of four. The smaller groups were not at the same physical location but rather distributed across different offices; a typical group setup could be two people in Oslo, one in Stavanger and one in Mumbai. Each small group filled out one PDF business mat together using teleconferencing phones and computer screen sharing. They answered by creating a PowerPoint slide with their answers, that they had to present to the big group afterwards. One person was doing the practical work of creating the slide, while others could see the work live.

We split up and followed two different groups as they went through the “mat” for 45 minutes. Each group was sitting in private in their own group room; we documented our observations by taking notes. Video or audio recording was not feasible due to privacy concerns and also not that useful since we were not looking at specific tasks or interactions but rather the broad strokes when it comes to learning.

9.2.4.2 Subjects

The users in this study were managers from all across Aker Solutions and from many different countries. Both male and female with age ranges from 30 to 60. They all have computer experience but the task ahead of them; setting up cross-location collaborative tools to solve the business mat was new for many.

9.2.4.3 Result

The initial reaction was that the split location added a lot of hassle, out of 45 minutes only half was actually spent working on the task. The other time was spent setting up the connection and tele-conference equipment. That was also part of this workshop, to practice the technical setup.

The latency and lack of visual feedback made discussing difficult, participants only made statements without going into detail. They were more concerned with getting a “correct” result that they had to present later, than actually discussing; and time was a very limiting factor. Being forced to present their answer afterwards made sure that they actually put effort into the work, but at the same time getting correct or acceptable answers became more important than discussing.

A lot of time was spent on practicalities like formatting the document and correcting spelling errors. The need to write things down like this was carried over from the physical mat where one user would write answers with a pen. Having to actually put down the group’s answers makes sure everyone actually agrees, but in the free-form tool that is PowerPoint a lot of time was wasted on making it look good, especially since they needed to present. A digital business mat should not allow this possibility to polish the appearance of the answer, especially if they have to present it.

9.2.4.4 Discussion

The results from this observation were useful but somewhat limited. Split-location adds a whole other set of technical problems than the ones that have to be considered when designing a co-located business mat. The time limitations and time wasted setting up the equipment also made it difficult to draw any conclusions about what would happen if they had more time. However, we have got some useful information as well. Prevent users from formatting and styling their answer. And make sure the interaction is so easy to understand and hassle-free that it does not steal focus from the task at hand.

9.2.5 User Study Business Mat

Figure 7

9.2.5.1 Method

This user study was conducted at Aker Solutions' internal employee cross culture workshop (Figure 7). There were five tables in one room and each table had four persons sit around. The workshop started with a short introduction of the concept of cross culture and the Lewis test was mentioned as well. The Lewis test is an online test for knowing your own culture profile by answering 60 questions. Each workshop participant has done the Lewis test beforehand. The test is also quite relevant knowledge for working with this particular business mat. After a short introduction, each table started working with the business mat on their table. Ideally we should film all five tables, but practically one camera on one table was allowed and we two people did observation of two tables each. The whole session took around one hour, with a break in the middle. During the break, two short user interviews were conducted.

9.2.5.2 Subjects

Subjects are similar to the subjects we observed previously in PDF version workshop. They are employees of Aker Solutions, mixed nationalities, ages between 30 to 60, managers.

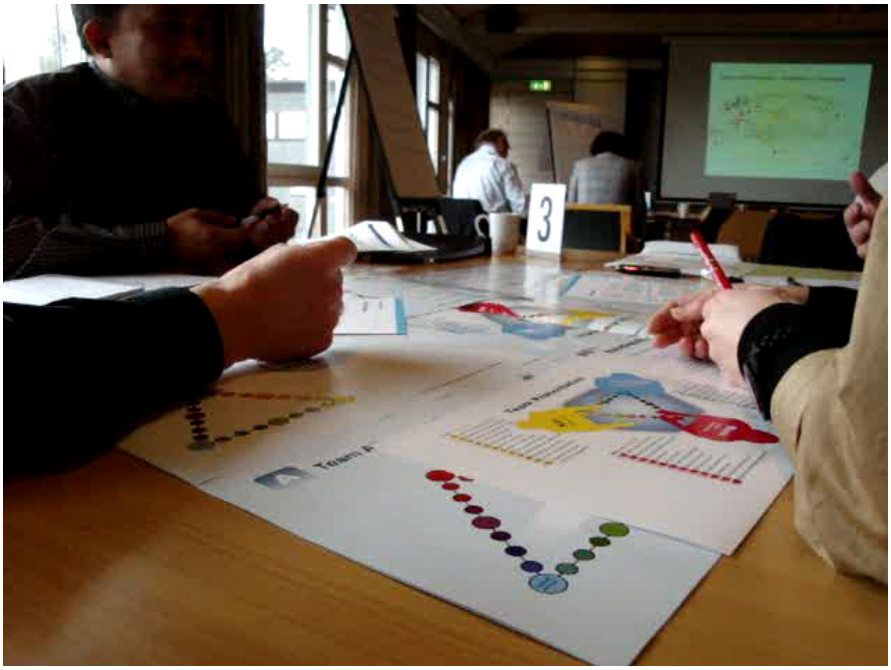


Figure 8

9.2.5.3 Result

One of the biggest problems we found is inequity of participation. The business mat has a very clear rule that all four people sitting around takes turn being in charge (Figure 8); which means they take turn reading out the introduction, the questions and being responsible for filling in an answer. Despite this rule many tables have dominant participants who take control all the time. At the same time, there are also users who keep quiet most of the time. Therefore, dominant users often write down their own answer instead of group's answer.

Groups sometimes lose their focus. It is quite easy for some users to work ahead or behind because of the possibility paper and pencil provide. One situation we observed was one user reading the next section while three other users in the same group are discussing another section.

Users change physical location and walk around the table to be able to read text instead of asking the person who is in charge to clarify. This might be an act of courtesy since walking around the table bothering yourself is less obtrusive than asking someone to re-read. But it removes an incentive to actually talk.

Some users complain that they would like more time than the business mat has specified.

9.2.5.4 Discussion

This user study was very useful for the rest of the work. From the end users' need we could translate them into design requirements which will be illustrated in the next sections.

When it comes to the working process, everything we have done in the pre-study section is very similar to the so called phase 0 in agile, and phase 0 being the most important for project's scope and structure. During phase 0, user experience designers translate final users' needs into design requirements. And during the next iterations, developers and designers can confidently work and

rework them. This kind of user research grounds the agile customer team in real user work practice, culture, goals, strategies, and issues. (Beyer, 2010)

9.3 First Design Iteration

9.3.1 Process

Taking the knowledge we gathered from the pre-study and literature review a number of topics were defined, in order to test different aspects of the problem. For example, is it necessary that one person do the answering or can you distribute that among the group. Here we list those topics and the scenarios we envisioned to test them. They are in turn compared with related features on the paper business mat.

9.3.1.1 Topic: One in charge of answering or everyone manipulating the screen

The natural interaction on a surface table is that everyone participates in the interaction, that is quite different from what is happening when groups collaborate around a paper business mat or a shared computer screen. We want to investigate what the differences are between one person answering versus everyone, since the former might be superior for learning in some cases. (Dillenbourg, 1999)

What follows are a couple of hypothetical effects that might appear when everyone interacts at the same time.

Positive

- Mutual interdependence between users through disjoint information and control. If each user has access to a distinct part of the task, everyone has to be involved in order to solve the task, which promotes collaboration. The dominant users have motivation and a reason to actively engage passive users in order to get their information and solve the task.
- More involved and intrigued users when there is an opportunity to actively participate.

Negative

- Easy to over focus on physical interaction instead of verbal communication. Users being too busy interacting with the application to discuss with each other, they focus on what they themselves are doing instead of discussing the task.
- Since everyone can interact the most dominant user might always take charge.

In order to test these topics we envisioned two scenarios.

9.3.1.1.1 Scenario 1

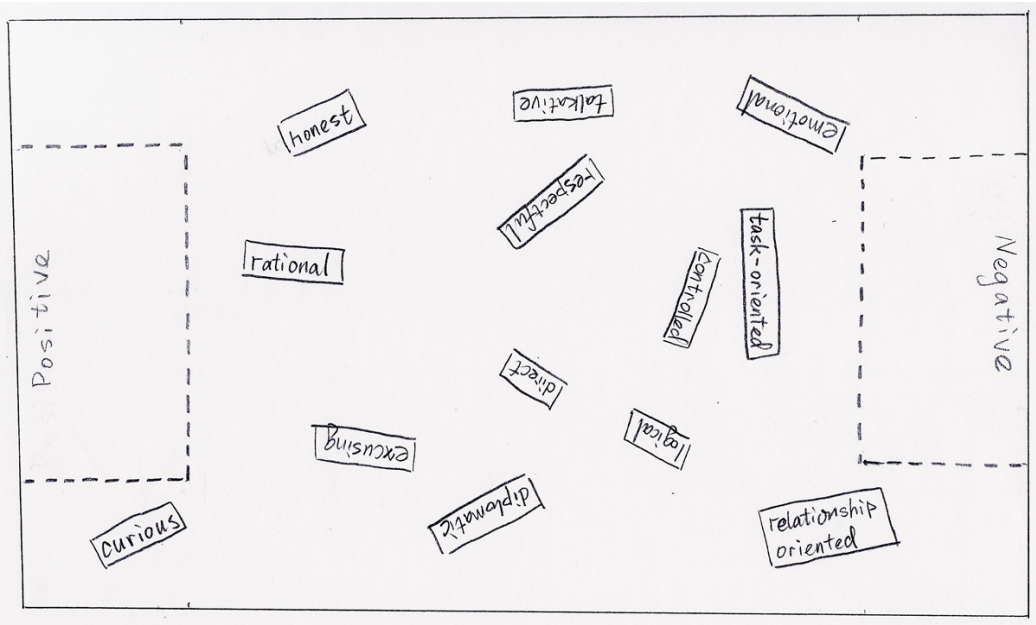


Figure 9

Users are evenly distributed around the table, just like in the paper version. Items containing answer phrases appear randomly on the table (Figure 9), the task is to sort them into two areas. Some items will be inside the users personal areas (Scott & Carpendale, 2010). We hope that these items in a natural way will "belong" to these users, at least according to past tabletop studies. Then they have to actively share them with the rest of the group which promotes participation through mutual interdependence. Theoretically this scenario provide interpersonal interaction, simultaneous user actions, orientation of short phrases and transitions between personal and group work.

9.3.1.1.2 Scenario 2

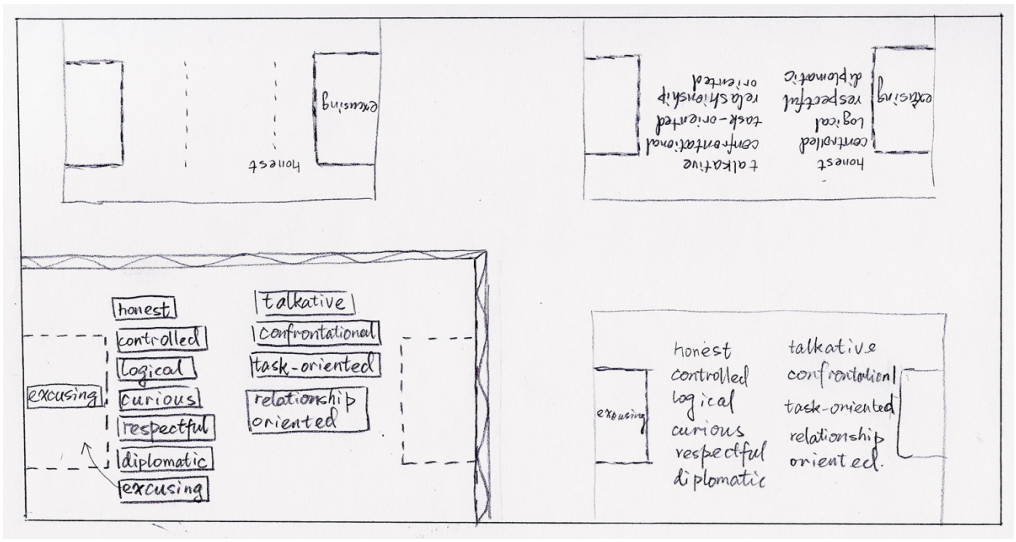


Figure 10

In this Scenario (Figure 10), the bottom left user is the lead user. The other three can not do any action but has perfect information about what lead user is doing. The hypothesis is that they can then focus on the discussion instead of interacting.

There are several reasons for this design:

- Based on the observation of the paper business mat, users had difficulty reading text which were not in front of them.
- We would like to test weather extreme inequality of physical participation would influence the verbal participation. (Marshall et al., 2008) suggests that equality of physical participation should have very no influence on verbal participation.

9.3.1.2 Topic: Frequently accessed information

In both traditional collaborative group work and when using the paper business mat users frequently need access to information to solve a task. We want to investigate in which way this type of information is best provided. If it should be done on the surface which has quite limited screen space, or on a separate paper. Also which way it is presented on the surface matters and we will investigate two different scenarios. To be able to test different scenarios, we choose the most "clean" content which has the lest interaction: one person read out the question and have control with the only keyboard to be able to type in group answer, while the others only can discuss. The information provided on the paper is essential to answering the question.

9.3.1.2.1 Scenario 1

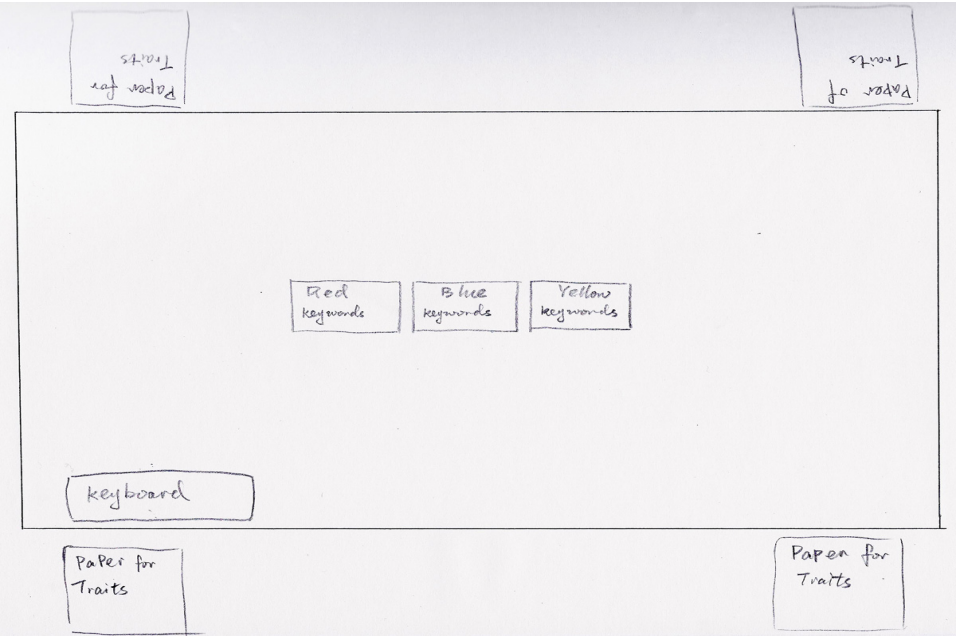


Figure 11

The information is presented on four separate papers (Figure 11). All of them have the same content. In the middle of the screen, the lead user writes the answer text so that all users can read equally.

9.3.1.2.2 Scenario 2

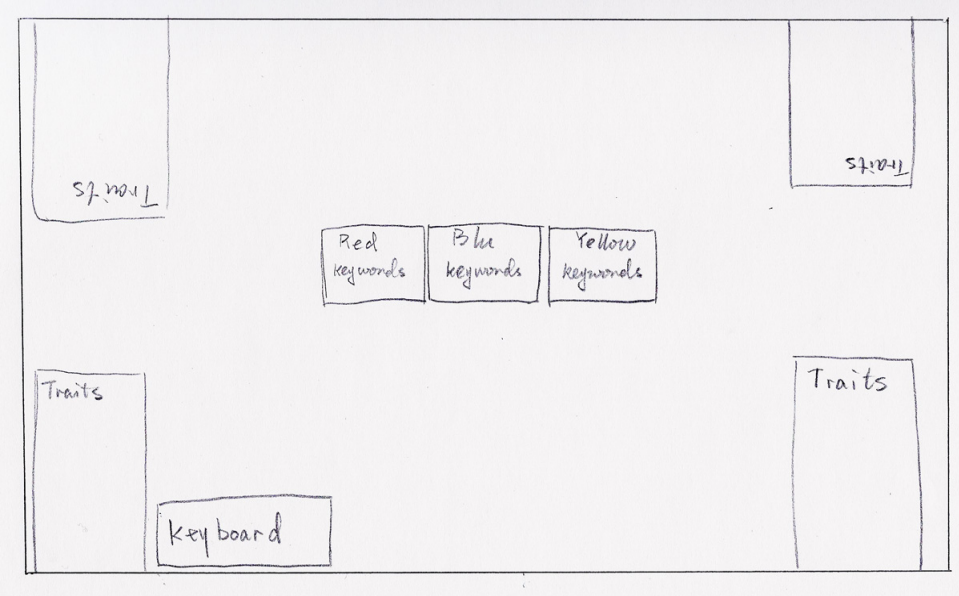


Figure 12

Very similar to before, one user writes answers in text boxes Figure 12. But here the other users can read the list with information on the screen right in front of them.

9.3.1.2.3 Scenario 3

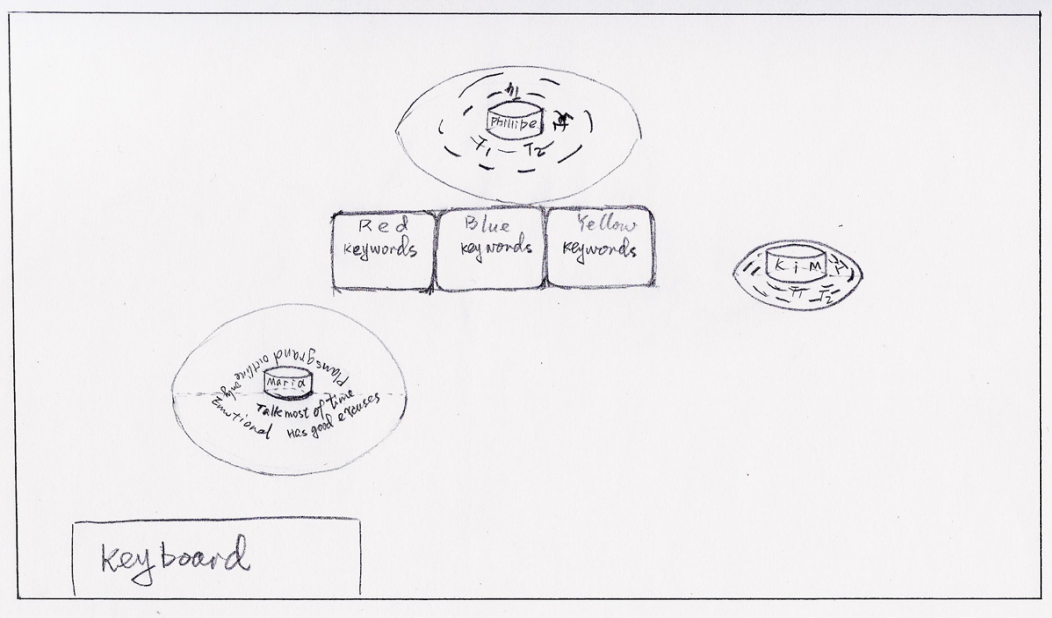


Figure 13

One user writes answers in text boxes (Figure 13), while the others can read the information around tangible objects on the table. In this case, instead of presenting frequent access information as personal list (four copies), the same information become group shared information (one) with three logic parts separated and represented by tangible objects with different appearance. We want to test if this imperfect information is a big problem for users compared to having the list all the time. Also if the tangible objects promote collaboration compared to everyone reading by themselves.

9.3.1.3 Topic: Encourage or Enforce verbal participation

If the goal is to get people talking, there are different ways of doing so. Here we want to investigate how you can encourage and enforce users to discuss through prompts or instructions. The existing business mat already encourages users to discuss with written instructions, and there is also a facilitator shared by many tables prompting users even more. With an interactive tabletop we have the opportunity to not only encourage, but also enforce users to discuss with direct instructions to each specific user. We want to test how the user perceives this and how well it works.

9.3.1.3.1 Scenario 1 (Encourage)

The same scenario as in the first topic's scenario 1. As long as the answer of a module requires a group discussion we already enable them to discuss. In this module we also encourage it by distributing the possible answers into users personal areas.

9.3.1.3.2 Scenario 2 (Enforce)

To enforce users to discuss, we have designed module 1 to test. There, each step is presented clearly and users have to follow it 100% to be able to go forward together. Short text is used as guide, for example ”Drag your choice into middle and explain the reason.” Therefore, in this way everyone is forced to do the task and talk. One big advantage of doing so we believe is to avoid some user dropping out of the discussion which happened during the workshop with the paper version of the business mat. From a group learning's point view, we have defined a goal that the best learning result comes from everyone's participation.

9.3.1.4 Topic: Transition between Activities / Modules

In comparison with the paper mat, which has all information printed on one side of a A1 sized paper sheet, there's a challenge when it comes to design transitions between modules on an interactive table. There is not enough space or resolution to display everything at once, and it might actually be good to have them focus on one task at a time. In other words, how to tell users where they are in the whole mat process when each module is presented full screen. The pre-study showed us that users are impatient and often split the group's focus by proceeding without everyone being ready. We need to find a way of moving the group together as one unit between activities. Luckily that is a lot easier on a tabletop display than with a paper and pencil, we can control exactly what users are able to see and do. The challenge is how to do it intuitively and coherently, and on what level to do it: for each small sub-task or for each module.

9.3.1.4.1 Scenario

We start by making each module take a 100% of the screen, there is no way to see or read what comes next. We also make each module very specific, one module in the digital mat is equal to the content of one sub-question on the paper mat, just one question at a time, to make sure that users stay focused every step along the way.

At the start of each module in the paper business mat there is always a brief introduction that explains how this module works. In the mat about Cross Culture - that we get content from - this also

include a short briefing text. In order to keep everyone focused on this instruction we block the interaction with a semi-transparent black screen. The briefing paper is presented in front of one user who gets the instruction to read the text. A reason we keep one person reading as the paper version business mat, instead of giving each user the same text is that the two stakeholders (workshop manager from Aker Solution and group learning researcher) believe that by physically reading it stimulates the participants to talk more easily. Users also read at different speeds, separate texts would leave fast users waiting for the others. Once the user in charge of reading is finished and taps "Start Task" the black screen fades away and the users can start interacting. The hope is that this will keep the users focused long enough to understand the instruction. The piece of text is also draggable for users to pass around as a real paper.

When a module is finished we have to transition the whole group together again, we envisioned three different ways of doing this.

9.3.1.4.2 Submit Scenario 1

Here the user in charge simply clicks "submit task" and the whole screen changes to the next task.

9.3.1.4.3 Submit Scenario 2

Here each corner has a button that has to be clicked to move on. Each user has to indicate they are ready by tapping this button, similar to many ready-systems in online games.

9.3.1.4.4 Submit Scenario 3

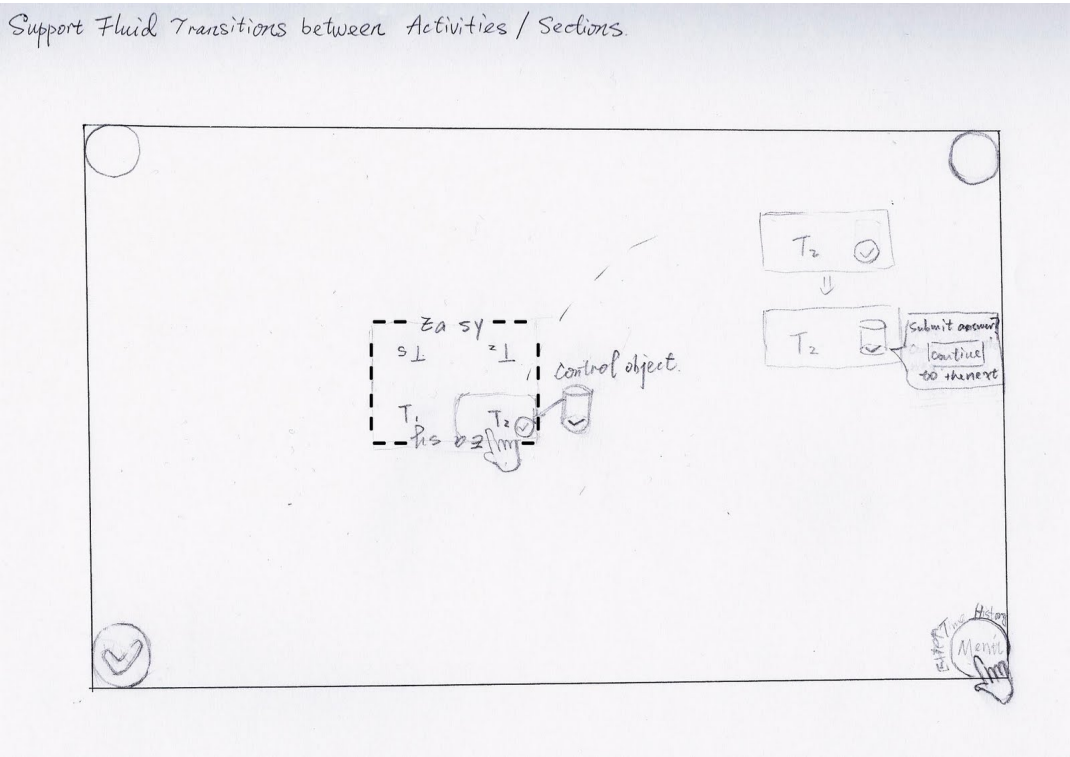


Figure 14

In this scenario (Figure 14) we envision a tangible "leader object" akin to a "talking stick". The person in possession of the object is in charge of proceeding and submitting, and the object changes owner

between modules. In order to submit a module, the object has to be placed in a submit area in the middle and then confirmed with a click. the idea of this "decision" object is very similar to the "start task" button on the introduction text paper before each module. We assume that the person will ask whole group before do actions which influences whole group's process on interactive table. In order to proceed to the next module the object need to be moved to another user's corner, indicating that the next person is now in charge. Any instruction that has to be read aloud would appear in vicinity of the leader object.

9.3.1.5 Topic: Open Questions

Open questions are questions that allow any kind of text as an answer, i.e. an empty text field. On the paper mat they are quite common and requires about 1-3 sentences of text. In the pre-study we noticed that these types of questions work very well, a lot better than check-boxes or multiple choice questions for example because most of the time users choose to vote to avoid discussion. On a tabletop displays however it is not so natural to input text in comparison with dragging and dropping existing objects, and it is not so easy to read text from all directions when it comes to long sentences. We would like to explore alternatives to writing long answers to these questions. Here are a couple of solutions we expanded into scenarios and tested:

- Write keywords to sum up the discussion instead of writing long sentences. We believe the act of writing is more about having everyone agree on one common answer, than something that has to be extremely clear. Keywords might be enough for this. And keywords would be readable from all directions without problems (Wigdor et al., 2005)
- Show result of one person's typing in the middle of the table and be able to re-orient the text.
- Have a copy of the text mirrored to the other side of the table.

9.3.2 Resulting modules & User test

Having defined topics and problems to study, the next step was to implement and test them. Ideally we would like to be rigorous and test with real end users in the environment the application is intended to be used, as we did in pre-study. "The greatest potential of carrying out observations in the users' real environment, Leonard and Rayport argued (Leonard & Rayport, 1997), is the possibility of observing unarticulated needs, that is, problems that the users encounter but do not know can be addressed or do not even recognize as problems" (Engelbrektsson, 2004). Another important issue for the user test is choice of participants. "For the purpose of building general theory, the experiences of subjects from an experienced user category may provide undesired bias. However, in product development with the purpose of satisfying a specific user population, these experiences must be taken into consideration and in fact not using the actual user population could result in invalidating the outcome of a test." (Johnson & Baker, 1974). Since we are working on general theory on how to introduce multi-touch surface into DC learning, we decided to not test with experienced users. Therefore, we tried with local people with cross culture experience to do the user

test. As mentioned before, our study is different from ordinary product development, so all users for the test are inexperienced users and the tests are made in a laboratory environment.

In the end, time and resources were limited so we decided to combine different topics and scenarios into unified modules that could be tested with one group. The different modules are described in the upcoming sections.

9.3.2.1 Subjects

For this user test the subjects are four university students in ages 25-35, two male and two female. They have a lot of computer experience but are quite inexperienced when it comes to multi-touch. They have no prior experience of the business mat or the cross culture concept, but they all have extensive personal cross-culture experience, something needed to solve the tasks in the cross-culture business mat.

9.3.2.2 Method

Figure 15

The test is performed in a room in Touchtech's office where the users can sit undisturbed (Figure 15). The whole test is recorded using a video camera.

First we give a short introduction of the cross culture concept and the concept of a business mat; the same kind of introduction that all users of any business mat gets. The users then perform the icebreaker part and three modules of the paper business mat. After that they complete six modules on the digital table. The purpose of this is to be able to compare approximately, what (if any) differences there are between the two tools.

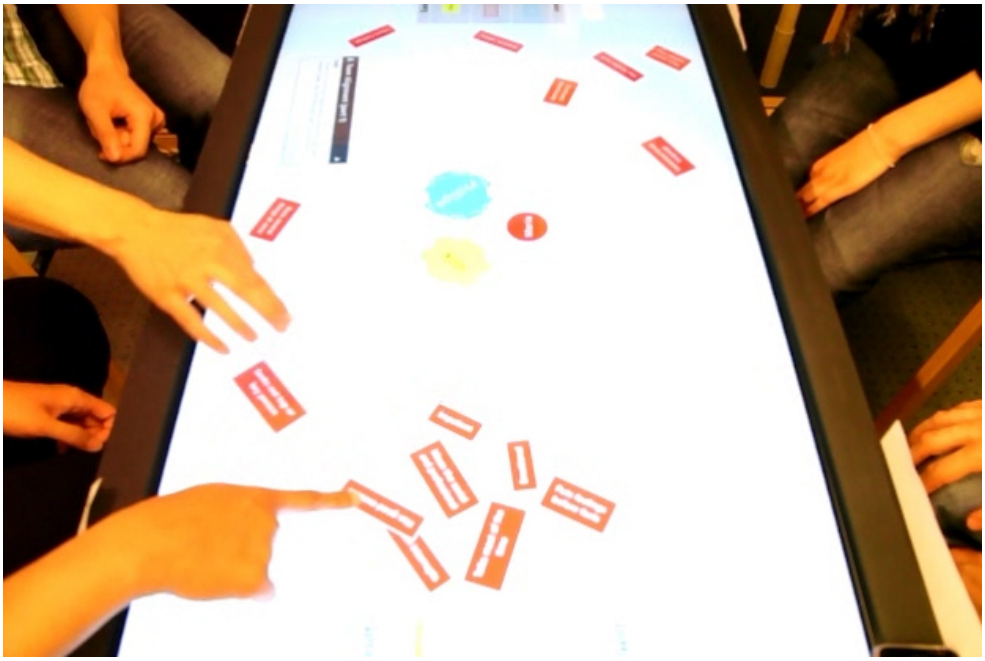


Figure 16

A 42” HDTV screen laying down with an IR frame was used as tabletop display (Figure 16), it supports up to 20 simultaneous touches. The users sat around this table in chairs, one person at each corner, the table is roughly 10 cm above knee level. The Surface 2 was not available yet so this acted a suitable replacement. Since the Surface 2 has better specs in all aspects (screen clarity, touch delay, simultaneous touches etc.) we would not "hide" any potential interaction problems, i.e. if it works on this screen it should work equally good or better on the surface 2.

9.3.3 Module Results

9.3.3.1 Module 1

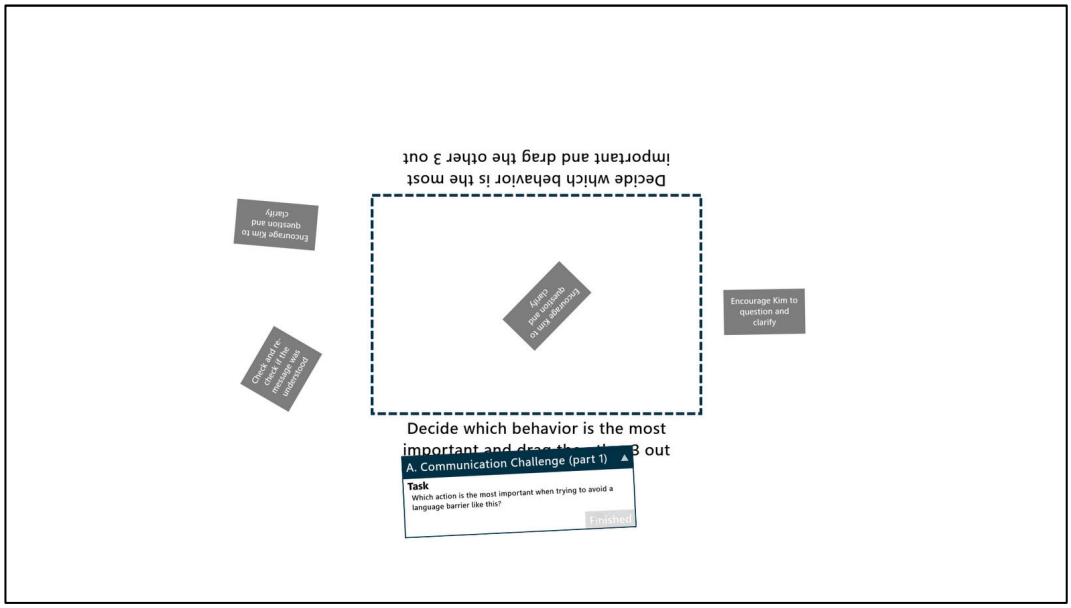


Figure 17

9.3.3.1.1 Description

In this module (Figure 17) each user first has to make a choice individually, the choice is made between 7 different options on how a character is supposed to act in a fictional scenario. After each user has made a choice they are instructed to one by one share it with the group by dragging it to the middle and explaining. This is done with a small text box above each user's choices. After all users have explained they have to pick one of the four options as a final answer.

The purpose is to test how enforcing users to act in a certain way affects the interaction, discussion and user experience.

9.3.3.1.2 Result

There is some confusion as to how this module works. It is very strict in how the users can interact and they have to follow the written instructions precisely. This proves difficult, partly because of poor instruction/design but also partly because it is the first digital module they interact with. This type of high cognitive load module fits better later in the mat.

When it comes to discussion the users quietly considered all their individual choices, all of them making a conscious decision and weighing the options. Each user also presents their motivations when prompted to. There is a problem with the application proceeding automatically to the next user as the previous user drag their choice to the middle. They all prefer to drag the item before or at the same time as explaining, and it interrupts them when they see the next user's area light up from their dragging action.

When deciding on the final choice three people picked the same answer so it comes down to a majority vote. Unfortunately not sparking so much discussion.

Overall this module works as designed, it forces both verbal and physical participation making sure everyone both interacts and talks. Unfortunately the design lacked in clarity at some steps. Also the risk of the users being able to vote in the final step is problematic. We have noticed users often try to avoid conflict by voting, thus reducing discussion. When making this type of very strict module it seems you can lift even the most passive user to become active, but they all rely heavily on the instructions and guidance from the interface, so that has to be extremely clear and well thought out. In this case the high probability of coming to a 3 against 1 voting scenario at the last step really discourages discussion. In some way you also remove the user's creativity and ability to think by themselves by giving instructions all the time. This could be good in some cases, but it has to be kept in mind.

From the study of this module, we notice that the content is very important for the result, any kind of interaction solution can not fix bad content; bad here meaning a question or problem that doesn't inspire discussion. If among the choices there is a clear winner, there is no need to discuss for example. At the same time, picking a bad interaction solution can really destroy good content. Both have to be carefully considered and both have to match each other.

9.3.3.2 Module 2

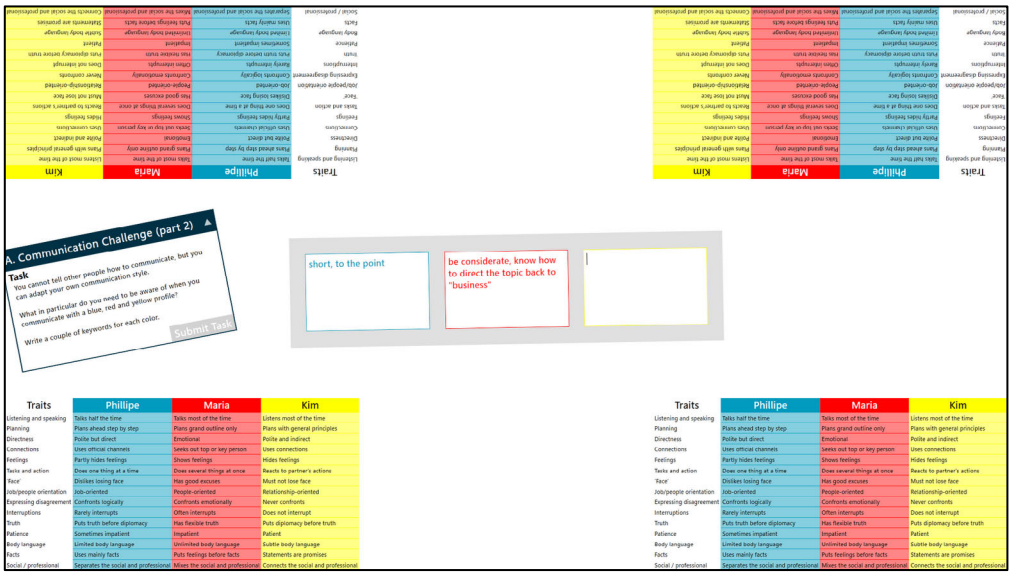


Figure 18

9.3.3.2.1 Description

In this module (Figure 18) the users have to answer what they should consider when communicating with three different fictional characters. One user writes the group's answer for each fictional character: Blue, Red and Yellow. They are instructed to type a few keywords as answer and do the typing with an external keyboard. The center answering area is rotatable. The tables in the corners contain vital information about the three characters and has to be accessed frequently in order to solve the task. The tables are initially collapsed to reduce cognitive load and clutter, they expand either by a tap from the user or by starting to type in the answer box. Typing in the blue box will expand the blue column for each user for example.

The purpose is to test how users react to having frequently accessed information on the screen in this way. If and when they turn the answer area to allow others to read, and if keywords is a feasible answering mechanic for open questions.

9.3.3.2.2 Result

The users quickly start interacting with their data tables. The animation of expanding and collapsing the columns proves to be quite playful and this distracts from the task at hand for a while. Eventually they start filling in the answers and keywords seems to work quite well. There is discussion and the users often look at their tables for more information. They never turn the answering area, except by mistake in the beginning. Either because they can't be bothered to read, or because the keywords make it possible to read from other angles. It could also be that they don't want to disturb the person that is typing. A lack of affordance for the turning action could also be the reason.

Even though they play with the tables at the beginning, when they start actually discussing they stop playing around and use what they need from the tables. Having this kind of frequently accessed information on the surface seems to work.

9.3.3.3 Module 3

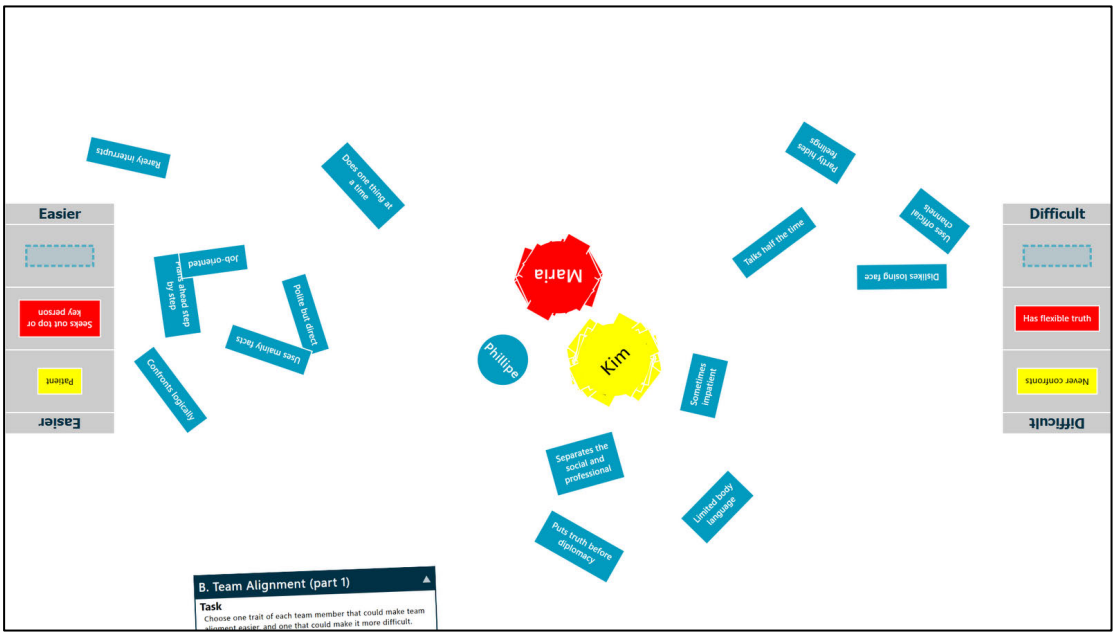


Figure 19

9.3.3.3.1 Description

In this module (Figure 19) the users have to pick from 15 different personality traits from three different fictional characters. They have to pick one trait from each character that make it more difficult and one that makes it easier to achieve “team alignment”. They pick by dragging a choice to either target area at the screen’s left and right edge. Therefore a total of 6 traits have to be picked out of 45.

The traits are initially hidden under the characters circles in the middle, after tapping a circle that character’s traits will explode out and scatter across the table, ending up in different people’s personal areas oriented towards them. Clicking another character will collapse the current one (saving the state) and expand the new one. Thus forcing the group to consider one character at a time.

This type of module follows the guidelines for tabletop design quite well. All texts are short and readable from all angles. It involves people’s personal areas and allow them to transition between personal work to group work. One thing we want to test is how well the personal areas work for encouraging people to participate. If it is better, worse or the same as the enforcing module.

9.3.3.3.2 Result

There is some confusion about how the circles work, if they should be dragged or tapped, but the users quickly figure out that they have to tap them, and that only one can be active at a time.

What follows is that all users quickly and quietly consider the traits in their vicinity and sort them close to either edge or in the middle depending on where they think they belong. They also reach over the table to correct what they believe is a misplaced trait. After a short while the table has three groupings of traits: those that clearly make it difficult, those that clearly make it easier and those in

the middle. In a way the tabletop now visualizes the group's distributed cognitive model of the choices at hand. The next step is to pick two final choices, the users do this by considering the traits grouped around each target area. They discuss which one to pick and strengthens their arguments by nudging their preferred choice closer to the target area. During the discussion the table thus keeps visualizing their distributed mental model all the way to when they make a choice. This is repeated for each of the 6 choices they have to make.

Picking just 6 options from 45 can be quite a task to do efficiently and with full coverage, especially as a group. This 2D version of sorting and prioritizing quickly allows the users to achieve a state where they can indicate and visualize their opinions and start discussing the final choice. Compared with users quietly reading traits from a list and just talking about them it both enhances the efficiency, coverage and discussion.

Overall this module works very well. There are very little instructions or guidelines compared with Module 1, but still the users do their best to solve the task thoroughly and everyone participates. They also consider all the traits without being told to do so, it's as if leaving a trait untouched or not considered in your corner of the table is unthinkable. It is in your personal area and you have responsibility to consider it for the group.

9.3.3.4 Module 4 & 5

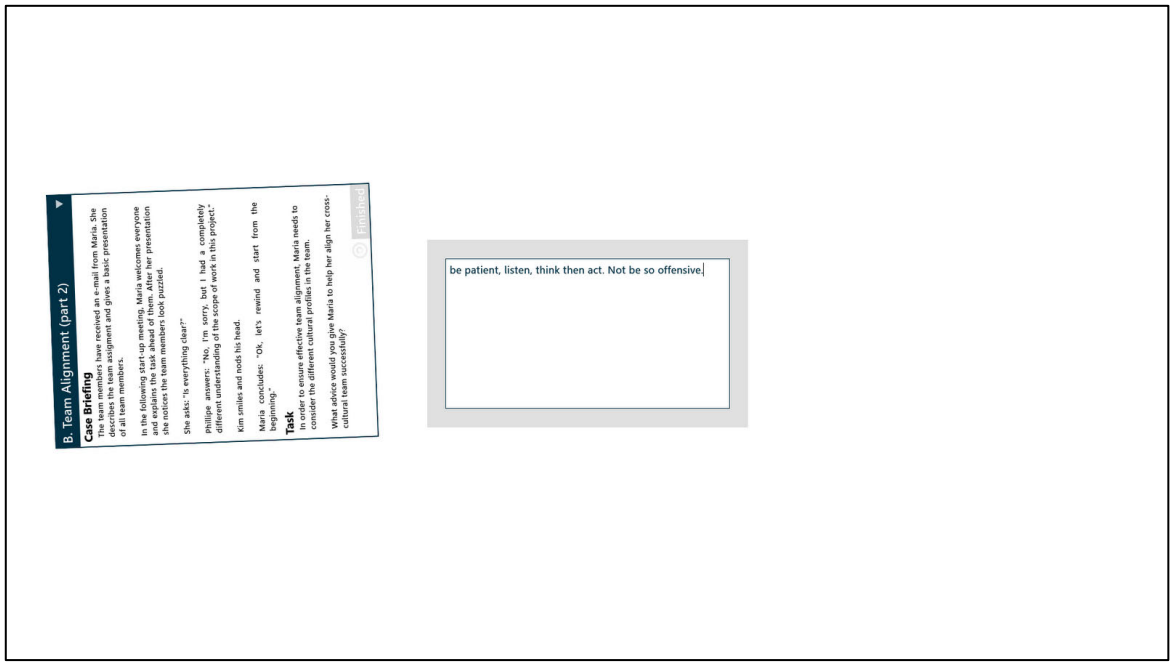


Figure 20

9.3.3.4.1 Description

In these two modules (Figure 20) the groups have to answer an open question with a written answer. One user is typing the answer for the whole group with an external keyboard. The answer area is rotatable. The users have access to the traits as pieces of paper next to the table.

The purpose is to test if an open question in the exact same style as on the paper mat with a simple written answer works in the same way as on the paper mat.

9.3.3.4.2 Result

The person in charge of the keyboard is actively asking the other users about their opinions, much more than when all users are equal. He talks the most because he feels responsible for the group's result. At the same time the other users have nothing to do other than discussing, they have nothing to interact with. This results in other users sometimes losing their interest and focusing on other things. The lost interest is not only about one person being in charge, it's also about the individual motivation of the users.

The users complained about having to use an analog keyboard when they have a multi-touch table in front of them that theoretically should be able to support a virtual keyboard. This says something about living up to user expectations about technology. If you can do something, taking the easier route can lead to disappointment. Similar things could be said about the introductory briefing, which right now consists of only text. The users complained that it could, and should be more graphic, perhaps a video or comic. This could also be because the subjects in this test were very technology literate. The reason we went with a physical keyboard rather than a virtual one had more to do with implementation time constraints than a real design decision, but it is important to keep that in mind for a real product

Overall the modules works similar to the paper business mat, this shows that the same kind of result can be reached as with paper. One extra benefit is the ability of all users to immediately see the written text, this prevents the user in charge from writing anything they like, and also prevents other users from dropping out of the discussion. If they can see what is being written, they often have comments or opinions.

When it comes to discussion, these modules are some of the better ones. Because of the minimalist interface and low intractability, verbal participation become the only thing users could do.

9.3.3.5 Module 6

Figure 21

9.3.3.5.1 Description

The purpose of this module (Figure 21) is to test if keeping the original concept of the paper mat with one person answering is valid in a digital mat. Here the lead user is answering by sorting all labels into either helpful or unhelpful. The other three users can see exactly what is going on in three mirrored “screens”, but they can not interact.

9.3.3.5.2 Result

The users were quite confused by this module, they all tried to drag around the items in front of them. Eventually they all reached into the active corner and dragged those around. No one really read in their own corner so three quarters of the screen was wasted.

This module doesn’t create a lot of discussion, mostly because the items are too easy to sort: they are either obviously helpful or unhelpful. Overall this module does not work very well, it’s style of interaction was confusing and not in line with Microsoft’s design guidelines (Microsoft, 2011). It is however a useful experiment because it informs us which road not to take.

9.3.3.6 Briefing paper

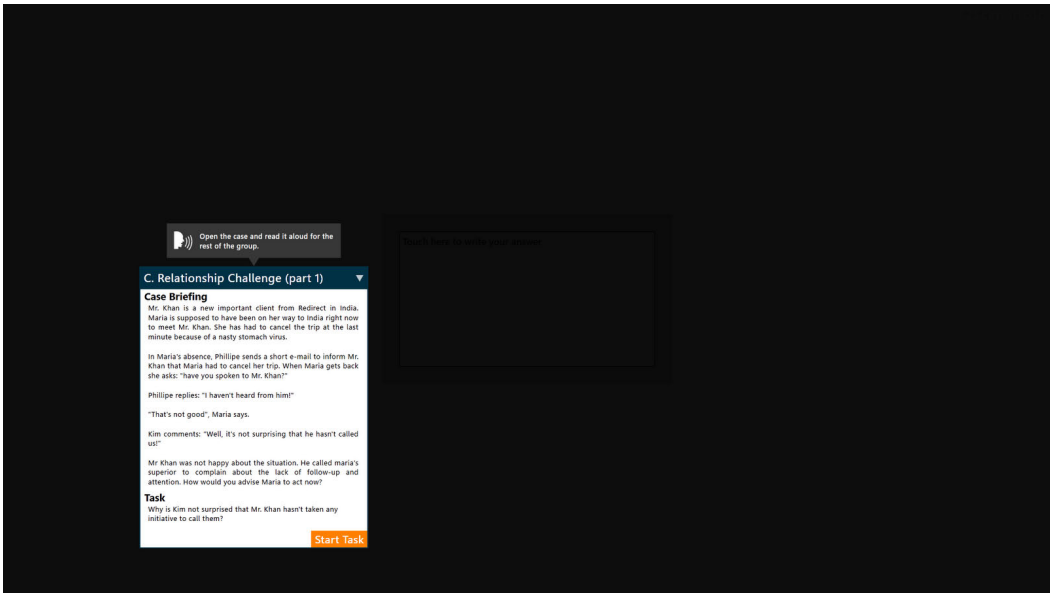


Figure 22

9.3.3.6.1 Description

In the paper mat a short background is given to the problem at hand before each module. The lead user reads this and when finished the group starts solving the task. This seemed to work well in paper form so we wanted to keep this functionality but fix some problems. In some cases users are looking around on the paper mat trying to peek at future tasks or questions, this leads to the group becoming split and not listening to what is being said.

In the digital version we replicate this functionality as a “briefing paper” (Figure 22). It starts out collapsed with an instruction above that says “Open the case and read it aloud for the rest of the group”. After the user taps the header it expands to the full briefing paper. Having this functionality is an attempt to solve two problems. Information overload at the beginning of the module, now the instruction is very clear and the only thing the user can focus on. Secondly it teaches the user about the affordance that saturated colored rectangles are intractable, this is kept throughout the application. We went for simple saturated shapes in an effort to avoid shaded traditional buttons, they look a bit strange on 360 surface tables since they have to be viewed from all directions. Simple shapes is also in line with Microsoft’s “Metro” style and design guidelines for Surface 2. (Microsoft, 2011)

After the lead user has read the text and clicked “start task” the paper collapses to a half-state where only the task instruction is shown, the purpose of this is to conserve the limited screen space. Users can click the header to toggle it between this mode and the full mode with the full briefing text being visible. At the same time the background fades away and reveals the coming module.

The briefing paper is a regular scatterview item and can be dragged around and shared between users.

9.3.3.6.2 Result

This solution worked well. The lead users all understood what to do and followed the instructions. At the same time the rest of the group couldn't peek ahead or try to interact with anything so it kept people focused.

One "problem" is that users often sigh or complain about the huge quantity of text that expands after they click the header on each module, sometimes collectively laughing about the work that lies ahead of the lead user that has to read it. It is difficult to say if this is good or bad, having the group "fight through" challenges like this might actually be a good thing. (Tuckman, 1965)

Throughout the modules the users understood that saturated rectangles are intractable, it is difficult to say how much the briefing paper helped in that, but overall having saturated rectangles and shapes as "buttons" worked well.

One complaint from users was the need to read large amounts of text when the table in theory could display it as a video or perhaps in comic format. This again says something about living up to expectations. For this project having a good looking introduction is not really important, but for a real product it might be good to style it a bit.

The placement of the briefing text was completely random in this prototype, which proved to be a bit problematic. Being random it is very likely that the same user will have to read multiple briefing texts in a row, causing a feeling of "it is out to get me". For a real product having it semi-randomly appear, with all 4 getting it once before it repeats would be better. We believe this is better than predictably moving responsibility between users as is done on the paper mat. On the paper mat users can drift out of the task for long stretches since they know that their participation will not be required until 15 minutes later when it is their turn to read something. Knowing that their focus might be required by the group at any moment should keep them more on their toes and active.

9.3.4 Utterance Analysis

As the literature review part mentioned Utterance analysis is a theoretically sound tool for analyzing the user test. Therefore after user test we tried to implement this method. The whole user test was filmed to be able to analyze all utterances afterwards, this was done by transcribing all utterances into Excel and categorizing them by user. Unfortunately it was unfeasible to label all 1487 utterances and draw an interaction pattern from that. In another words, this analysis was abandoned due to huge amount of work.

9.3.5 Inequality Analysis

So how do the different modules compare, and how do they fare against the paper mat when it comes to learning. That is a difficult question to answer, but one important factor is the equity of participation. Here we compare all the modules when it comes to verbal participation from the users.

Module	Words				Total words	Inequality Index
	User 1	User 2	User 3	User 4		
Icebreaker	723	627	507	696	2553	0.09
Paper 1	377	258	102	83	820	0.42
Paper 2	490	192	222	306	1210	0.27
Paper 3	588	200	389	66	1243	0.47
Paper 4	324	112	114	171	721	0.32
Digital 1	128	74	90	59	351	0.21
Digital 2	314	317	253	77	961	0.27
Digital 3	227	334	372	323	1256	0.12
Digital 4	39	2	40	12	93	0.51
Digital 5	109	57	67	24	257	0.34
Digital 6	17	61	35	33	146	0.31
Paper Total	2502	1389	1334	1322	6547	0.18
Digital Total	834	845	857	528	3064	0.11
Total	3336	2234	2191	1850	9611	0.16

Table 1

Here we analyze using the inequality index (Table 1) mentioned in the literature review. A score of 0 is total equity of verbal participation and a score of 1 is a monologue, so a lower index is better. We also count the number of words each participant says.

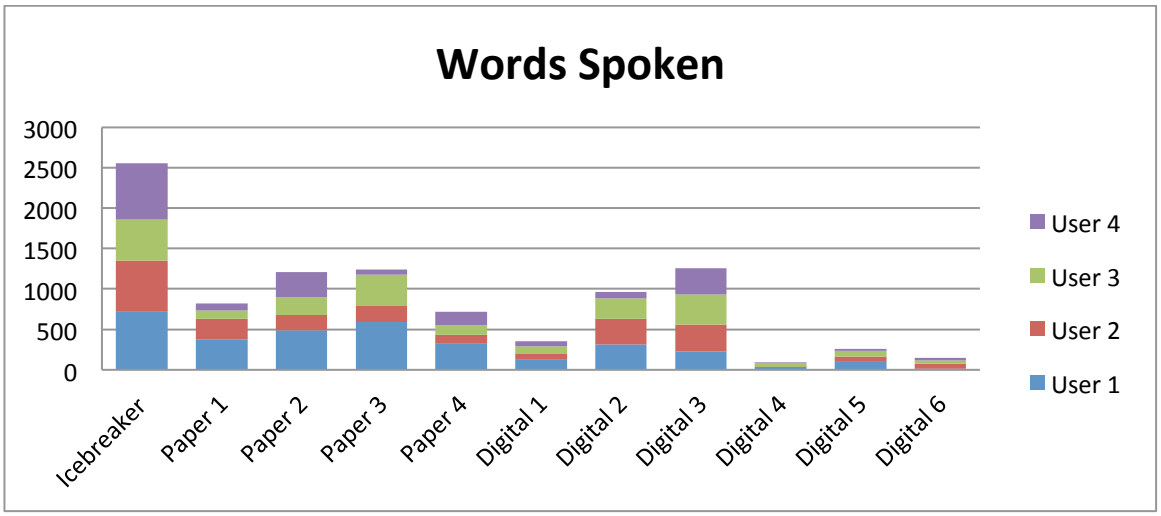


Figure 23

This graph (Figure 23) shows the number of words spoken in each module, categorized by user. It is important to take this graph in context of what the modules were. The complexity and difficulty of them varied greatly. The paper modules contained at least three questions each, while most of the digital ones contained only one. The purpose of the graph here is to show the varying data sources and their scope. Digital module 4 for example had an implementation problem that forced the users to continue prematurely and it can not really be judged either way, luckily module 5 is very similar and had more discussion.

It is also interesting to see the massive difference in the paper icebreaker module compared to the others, it has about as many questions as the other paper modules. One reason could be that the group is very motivated to do well on the first module. It could also be that they like to talk about themselves and their own opinions; the icebreaker asks them to introduce themselves and discuss their own personal biases.

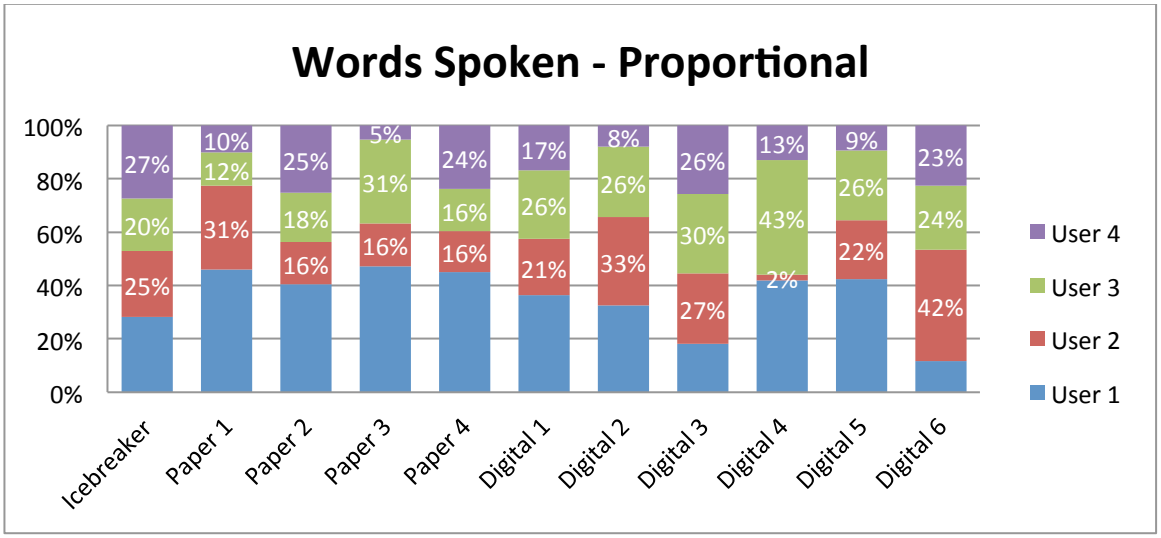


Figure 24

Figure 24 compares the proportion of how much each user speaks. As can be seen all users say at least something in each module, User 1 is also quite dominant in all modules but especially the paper ones. It is also interesting to note that in digital module 3 and 6, the most dominant user (blue) speaks the least of all. Digital module 3 relies heavily on augmenting the discussion with interaction. It is difficult to say something conclusive after only one user test but both the qualitative and quantitative results seem to indicate that module 3 is quite good at mitigating dominant users while keeping the discussion active. From the observation the reason the users are very equal in module 3 is due to everyone having things to say. In module 6 it has more to do with eagerness to finish.

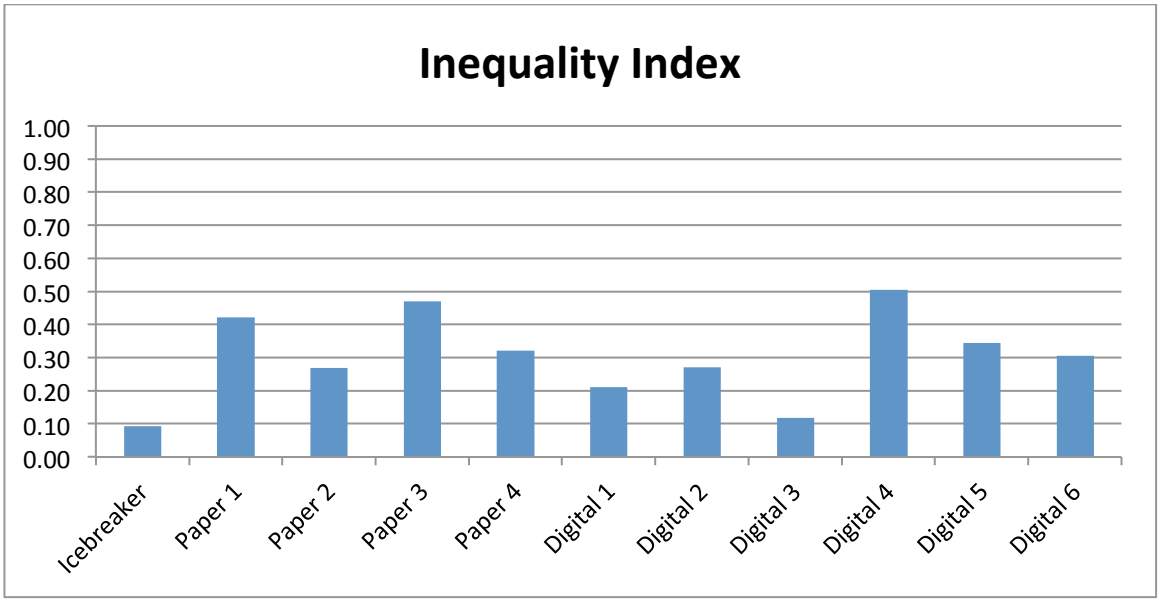


Figure 25

Like mentioned before, a score of 0 is total equity of verbal participation and a score of 1 is a monologue, so a lower score is better. As can be seen (Figure 25) the icebreaker and digital module 3 are the best at keeping everyone equal, they are also the top two ones when it comes to generating discussion.

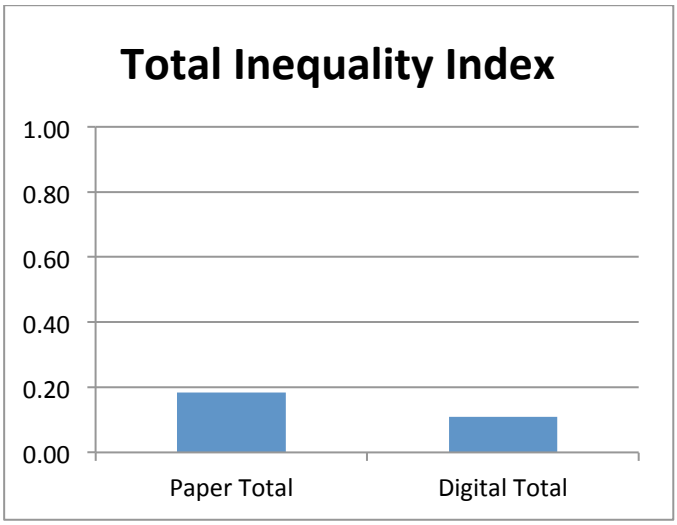


Figure 26

When comparing the paper and digital modules the digital ones slightly outperforms the paper modules (Figure 26). Again it is difficult to draw any conclusion with only one user test, but it seems like they are both in the same ballpark at least, which is an important result.

9.3.6 Discussion

Relying on both qualitative and to some extent the quantitative results we had a good idea of what worked, and more importantly, what didn't work. Based on this feedback we could continue with the

next iteration with plenty of ideas on how to improve. Since we are unable to get the same subjects and keep the same test conditions the next iteration is not directly comparable with this one.

9.4 Second Design Iteration

The modules in the second design iteration, and their user test results will be described in the upcoming sections.

9.4.1 Methods

The test is performed in Touchtech's office in an open area, other people are able to hear the discussion.

First we give a short introduction of the cross culture concept and the concept of a business mat; the same kind of introduction that all users of any business mat gets. The users then perform the digital mat from Icebreaker to finish.

A 42" HDTV screen laying down with an IR frame was used as tabletop display (Figure 16), it supports up to 20 simultaneous touches. The users sat around this table in chairs, one person at each corner, the table is roughly 10 cm above knee level. The Surface 2 was not available yet so this acted a suitable stand-in. Since the Surface 2 has better specs in all aspects (screen clarity, touch delay, simultaneous touches etc.) we would not "hide" any potential interaction problems, i.e. if it works on this screen it should work equally good or better on the surface 2.

A video camera is used to record the session.

9.4.2 Subjects

Due to time constraints the subjects were in various ways associated with Touchtech. Two were employees and two were master thesis students. So the users were familiar with each other beforehand. This is in contrast to the previous test where all users came from outside.

The subjects were all male, between 20-30 years old, with extensive computer and multi-touch experience. All of them had some kind of cross-culture experience.

9.4.3 Result

9.4.3.1 Icebreaker 1

Figure 27

9.4.3.1.1 Description

We keep the concept from the paper business mat, as the first Icebreaker's main purpose is to let people to know each other from a cross culture's point of view. The general theme of this question comes from a very similar question on the paper mat's Icebreaker.

Since we are not testing the paper modules in this user test it makes sense to have a digital module as icebreaker. Getting the group to know each other and talking is important for any kind of group work. We don't expect to get them through all group stages (Tuckman, 1965) into Performing, but having this kind of introduction might get some way into the Forming phase.

The module (Figure 27) gives each user a virtual keyboard which they can use to search for images on Bing Image search. The images found in image search can be dragged out from the personal area and manipulated as other Scatterview items. The task is to create a collage of the group's combined cross culture experience. Here we considered the transitions between tabletop collaboration and external work, being able to bring images from the Internet into a discussion on the tabletop. The hope is that users will share their personal experiences and get to know each other, while at the same time getting familiar with the touch interface.

In the design of this module we tried to emphasize the idea of personal work and group work, allowing users to work individually and transition to group work seamlessly. This is one of the main guidelines when it comes to tabletop work (Scott et al., 2003). We hope that they work individually, present it to the group and have a discussion about who shared what.

9.4.3.1.2 Result

This is a semi-successful module. The users were very interested in using the image search, they interacted a lot and explored the functionality of the tabletop. Giving them experience of typing and manipulating virtual objects, something which is important for future modules.

Unfortunately, group discussion was basically non-existent in this module. It can depend on a lot of things; the lab environment being an open public area which is not ideal, or unclear instructions for example. If the test was performed in a private room with clear instructions to discuss during the icebreaker results might be different. But the main problem is simply that the module doesn't require any discussion to be completed. Each user just drag in what they find, and then they are finished. All users can also do the exact same thing, no disjoint control exists, and they can do it at the same time. Parallel input has been found to decrease the opportunity for one user to dominate while on the other hand it has been found to result in decreased quality of discussion. (Marshall et al., 2008) Basically all users were too busy finding their own images. A redesign should address this, perhaps through a different task, or by simply reducing the number of keyboards.

9.4.3.2 Icebreaker 2

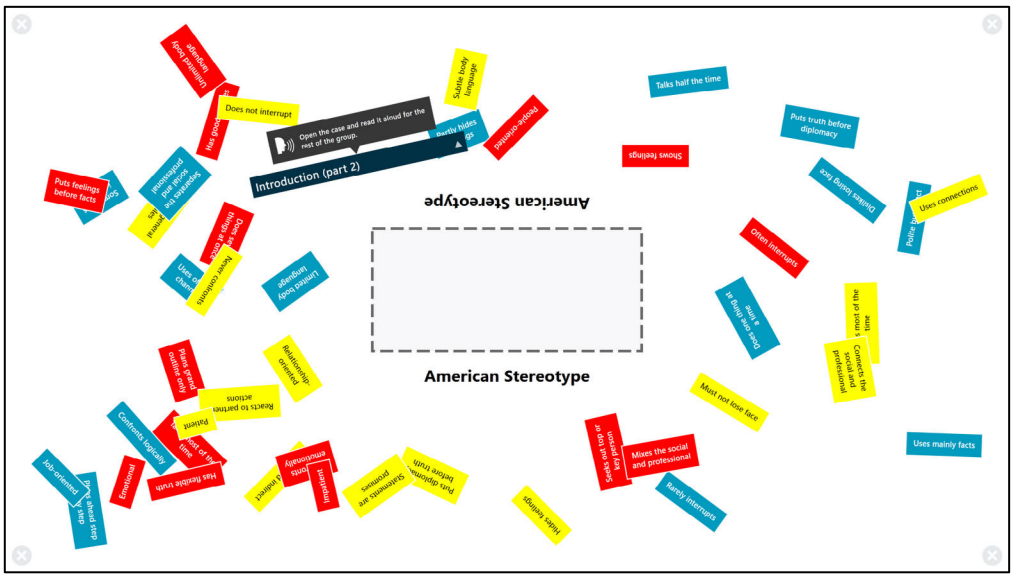


Figure 28

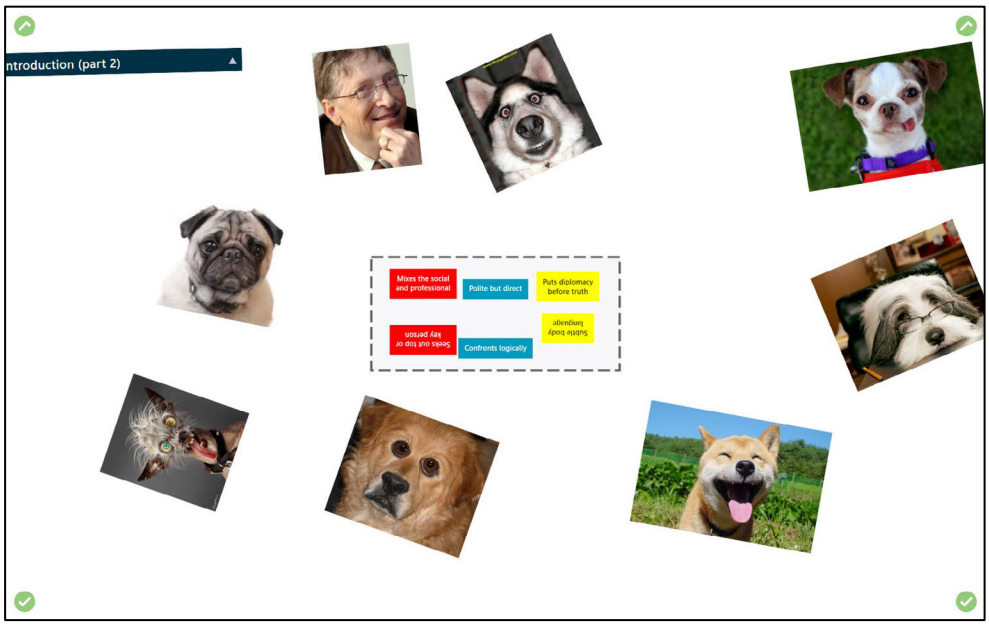


Figure 29

9.4.3.2.1 Description

The purpose of the second icebreaker is to let the users become familiar with the concept of Cross-Culture. The idea of this module is to let them to think about personal culture instead of national culture. The general theme of this module is taken from a similar module on the paper business mat.

At the beginning of this module (Figure 28) the group is instructed to choose among 45 traits from three different fictional characters. The group has to pick the ones that most signify a typical American stereotype. Doing this they are bound to generalize and think about national culture.

Once they feel finished and press continue they are presented with a new screen (Figure 29). The traits they have picked for building American stereotype are saved in the middle, at the same time many familiar diverse Americans show up in scatterview items. Hopefully an “Aha” moment will happen where they recognize the importance of personal culture over national culture, this is an important concept being taught in the original CC paper business mat.

Another purpose of this module is to test a large number of scatterview items on screen at the same time. Whether or not the group can handle 45 simultaneous labels with text scattered randomly.

9.4.3.2.2 Result

This module in comparison with the first Icebreaker is much more successful on group discussion. The first few minutes, each user is busy choosing traits which are close to them and putting into the target area in the middle. After that they start to see what others have chosen they start to argue with each other. There are some changes on the traits in the target area after discussion. In the end, everyone agree with the answer by pressing their corner button.

Having 45 labels did not cause a big problem, the users were able to sift through them effectively and consider most of them. They did however not cover all of them because some ended up in a passive

users corner and no one looked there. 45 items seem to be enough to tell the users “find some good ones but it is ok to not consider all of them”, which might be good for some purposes and bad for others.

We believe this module encouraged group discussion for two reasons: First a group conflict is created where everyone has different answer to the same question. Secondly each user “owns” different parts of the information of the task, which cause users to look on other users areas.

9.4.3.3 Module 1

Figure 30

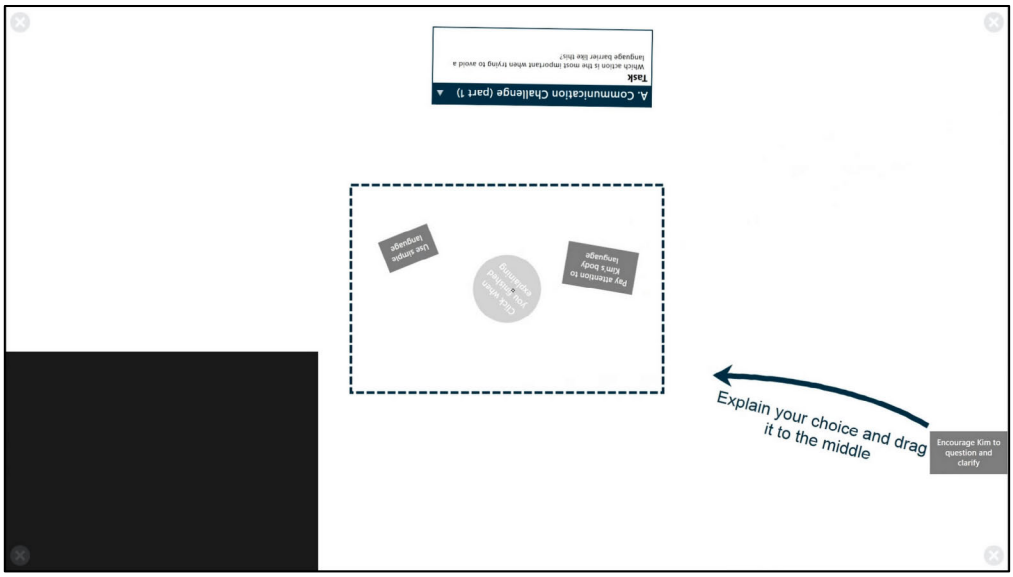


Figure 31

9.4.3.3.1 Description

This module is a redesign of the first module in the first iteration, see that section for a full description on how the modules works. Here we describe the changes that were made based on the first user test.

One observation made was that users tend to pick the same answers at the first screen. There are 1-3 “good” picks that are very likely to be chosen, and the users end up in a voting situation in the end. With two or three users having made the same choice, the group goes for that answer without discussing. As noted in the very first paper mat observation users like to avoid conflict and if there is a possibility to vote, many users choose to vote. In this redesign we wanted to avoid this, we wanted to get the users to consider all options and make arguments for as many answers as possible. There are 8 possible answers in total and on the first screen we force each user to pick individually between two of those each (Figure 30). In this way all options are considered and each user has some argument in their mind why one of their options is better than the other one they considered. Later when they have to present their choice and pick a final answer each user has at least one argument in their mind for “their” choice, and we never end up in a situation with two users having picked the same answer.

In the first version the instruction on what to do after all users have picked an answer was not very clear, it was just a text box above their answer and this led to some confusion. It was also confusing for the users that the software proceeded to the next user at the same time as dragging their answer to the middle. In this version we added a very clear arrow and instruction to drag in and explain (Figure 31). And after dragging in, the user has to click a button in the center to proceed to the next user.

9.4.3.3.2 Result

This module was successful to some degree. At least everyone talks, which none of the previous modules in this test did. However the second part of this module which force them to pick one out of four choices did not create any discussion. A similar situation as in the previous user test happened: they ended up voting but this time they all removed their own choice. In the end the person who believed the most in their own choice and didn’t drag it out became the group decision. So even though the design forced them to have different answers for the last step, they still ended up voting without discussion. This might say something about the difficulty in controlling user behavior through micromanagement, a better module could inspire them to actually be interested in discussing rather than trying to force it. Perhaps a combination of these techniques could be best.

In comparison with the previous module which encouraged users to discuss, this module attempts to enforce users to talk. It did create more equal verbal participation, but the conversation was very forced and lacked true discussion. This kind of module might be more useful for getting even the most passive user to say something, but not so good for really inspiring intense discussion.

9.4.3.4 Module 2

Figure 32

9.4.3.4.1 Description

This module is a redesign of module 2 from the first iteration, see that section for a full description. Here we describe the changes.

Instead of having one table close to each user in every corner, here we place one on each side (Figure 32), which should be enough for two users. We also disable the possibility to expand and collapse the tables, for two reasons: First of all it did not really add any value to the first version, users just played around with it for a while and then ignored it during discussion. Secondly it does not make sense to have this feature when two people share the same table, if one user collapses a table the other person reading might be interrupted for example.

Instead of using a physical keyboard this version has three virtual keyboards, one in each corner and each belonging to a different answer box. Different people therefore answer different sections of the question. The keyboards have different colors and become visible when you tap the respective answer box. We are hoping this is enough affordance to make sure the users know what is going on.

9.4.3.4.2 Result

The module again seems to work similar as to how it works on the paper mat. They discuss what to put in each box and use the tables to gather information about each character. Having a shared data table for two users was no problem at all.

Changing control between users by moving the keyboard proved quite successful, when the passive user ends up with control he actually asks the group to go back to his box when they wanted to proceed, because he had more to say and write down. This also proves how important it is to disable interaction for different parts of the question, here the keyboards of the inactive text box goes away when you move between them. Only allowing input into one box at a time, similar as to how module

3 works. This keeps the group focused on one subtask at a time. If all keyboards were visible at the same time it would give very different results.

If users learn that the control will jump between them like this, it can also make them more focused on the task. If they know that they might be responsible for input in the next minute it is more likely that they will focus on what is happening. Compared to one user being in charge of one whole module like on the paper mat, which takes around 15 minutes between responsibility swaps.

9.4.3.5 Module 3

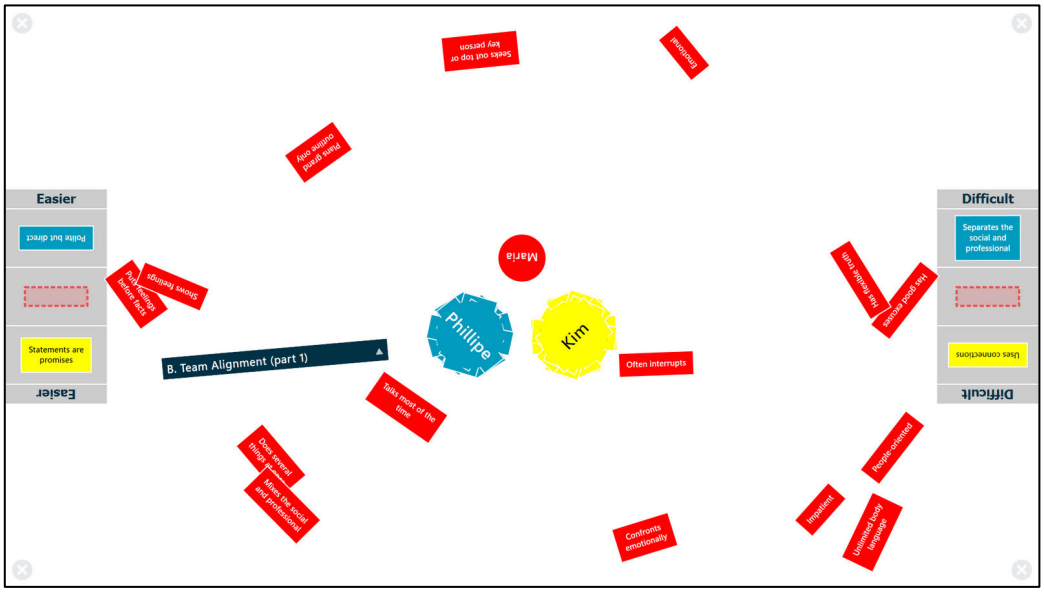


Figure 33

9.4.3.5.1 Description

This module (Figure 33) is kept identical with the first iteration. It worked very well and there was no reason to change it. Rather test the same module and see if we get the same result again.

9.4.3.5.2 Result

The result is quite similar to the previous user test. The users sort the traits close to either easier or difficult but not with the same speed as the previous group, some traits are left where they are as well. The discussion intensity is also a bit less than the previous group, but that holds true for all modules so probably has more to do with the lab environment and group dynamics of this particular group than with the modules. This module sparked some of the most discussion for this group, so even though the result is less discussion than the previous group, it is still better than the other modules for this group.

9.4.3.6 Module 4

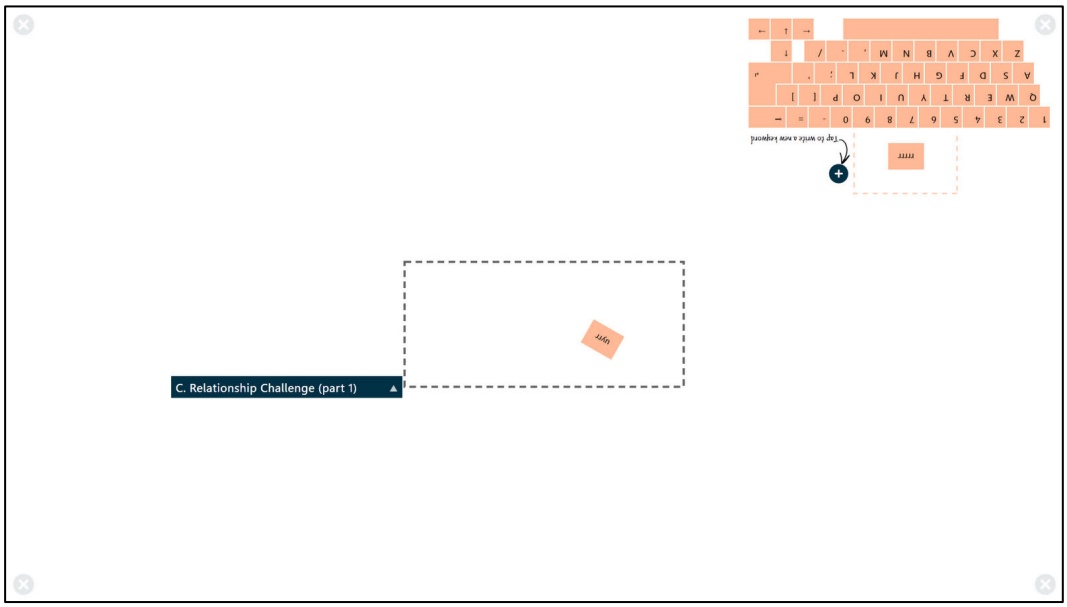


Figure 34

9.4.3.6.1 Description

This module (Figure 34) is a redesign of module 4 from the first iteration. See that section for a full description, here we describe the changes.

As before one user writes the answer for the whole group, but the physical keyboard is changed for a virtual one. This gives us greater control over when and how users can type, and who does it. It also allows multiple inputs at the same time, with a physical keyboard Windows only supports one user at a time.

The result from the first user test indicated that just writing in a textbox with a single keyboard is very similar to one user writing by hand on the paper mat. It resulted in similar discussions and therefore, with the possibilities of a digital tabletop we want to try to move beyond that. We got inspiration from module 3 where the users can drag around different traits visualizing their opinions as they discuss. Here the keywords that one user writes ends up as draggable labels, and they have to be put in the center as a final answer. In theory this allows users to touch and move around their ideas before making a final choice.

9.4.3.6.2 Result

Users found it difficult to sum up an idea into keywords. Keywords were not being dragged around and discussed as we hoped. Since only one person was in control, the keyword are a sort of decision from group already. There is no point in organizing or dragging them anywhere else than to the middle. When it comes to discussion, it was similar to the paper mat version of this question.

It is difficult to compare with the previous user test because this module had problems in the previous version. The users were unable to fully complete it because of a technical issue. However from what we could see, the previous group didn't have problem with writing keywords, they were however writing them into a textbox which might have made it easier, users are more familiar with

that kind of input. It could also be that the different groups interpreted the word keywords differently: this group seemed to assume one word for each “idea”, while the previous group wrote a couple of words for each idea. This should be clarified in the instructions in a future product.

9.4.3.7 Module 5

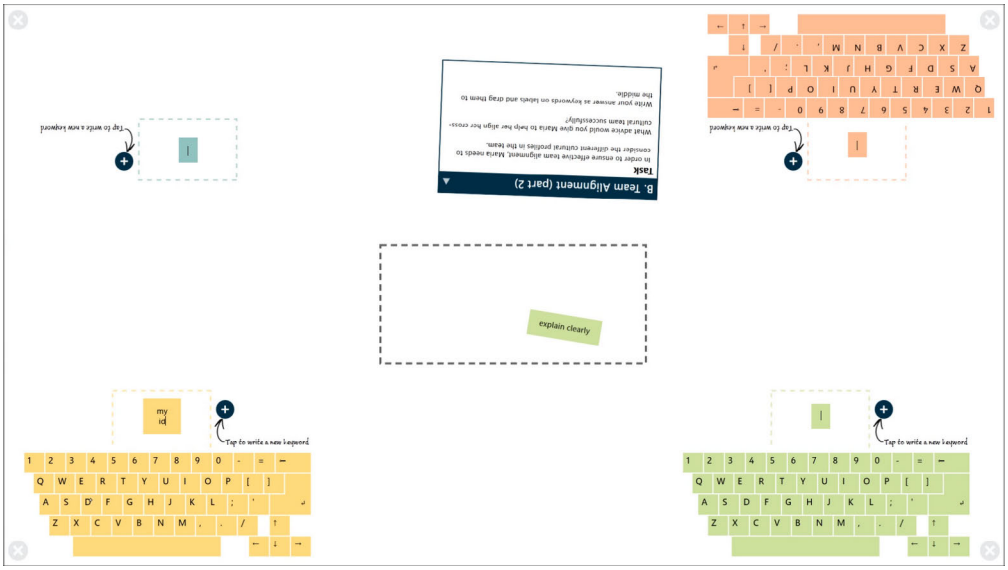


Figure 35

9.4.3.7.1 Description

This module (Figure 35) is a redesign of module 5 from the first iteration, and an expansion on the previous module in this iteration. See those sections for a full description, here we describe the changes.

In module 3 the ability for everyone to participate in the interaction seemed to produce good results. Here we give all users the ability to contribute to the final answer by writing keywords on colored labels, and combining all labels as a final answer in the middle. Each user has their own keyboard and color, and the labels can be dragged between users´ editing areas allowing collaboration. We believe this is a better way to collaborate on a common text on a tabletop than solutions similar to Google Docs where each user has their own caret to move around a common body of text. Here pieces of text can move between users personal areas and a common area. The pieces of text can be moved close to or into a final answering area as a way of organizing and visualizing the group’s mental model, similar to what happened in module 3. The pieces of text can also be rotated and moved individually allowing users to read more relaxed and also indicate which area of the text they are working on.

The purpose of having a color for each user, and having that color “stick” to the produced label is to identify which user the idea came from. There has been research done that identify the benefit on anonymous electronic brainstorming (Cooper et al., 1998), so in theory it would be better to not identify the author. That would result in more diverse and liberated ideas since the users don’t have to consider group dynamic or the opinions of others. The reason we choose to identify users anyway has more to do with the practicality of the tabletop than anything else, it is simply not possible to

type in complete privacy on a regular tabletop display so we decided to go for the other extreme. By identifying the users that come up with the ideas, we hope to inspire people to come up with more keywords by identifying their contribution visually. People tend to overestimate their own contribution to group work, something known as the Illusory Superiority bias (Hoorens, 1993). By visualizing exactly who did what one hope is that people that contributed less will feel a need to write more labels.

9.4.3.7.2 Result

The result for this module is extremely similar to that of Icebreaker 1. Each user is busy typing and thinking individually and no discussion occurs. Providing this kind of parallel work is good for making them think and everyone contributing equally, especially getting passive users who do not usually talk to participate easily. On the other hand it really discourages group discussion. To make this module better there should definitely be a group conflict after the parallel work, for example ask them to order their answers by importance or categorize them.

This module includes some new ways of interacting that was not familiar to all users. One thing that is good with everyone having parallel work is the opportunity to learn from each other. In this case one use was unable to create a new label, but learnt how to do so by watching the user sitting next to him perform the same action. It doesn't really help teach the Cross Culture concept, but might be helpful to teach novice users how to use the interface. Something which will be important if the user group is more diverse, one could have one experienced user helping three others learn the interface.

9.4.3.8 Module 6

Figure 36

9.4.3.8.1 Description

This module (Figure 36) is unchanged from the first iteration, see that section for a full description.

The reason we left it unchanged is to validate the previous result. The first result indicated that this kind of module does not work well at all, so tweaking it didn't make much sense. Instead we keep it as is to make sure the problems the first group had are common problems and not a fluke.

9.4.3.8.2 Result

The result is a bit similar to the previous user test, the users are quite confused as to how this module actually works. It takes a while to figure out that only one corner is active while the others are mirror images. In contrast to the previous group, this group doesn't reach over to interact in the active corner. Instead they sit passively and talk, but they prefer to look in the active corner rather than at their own corner, so again three quarters of the screen is "wasted". The items are still too easy to sort so no real discussion takes place, overall this test confirmed the previous result.

9.4.3.9 Corner buttons

9.4.3.9.1 Description

One problem that was identified both in the pre-study and after the first user test is that is difficult to get the group to proceed as one unit. Having the modules in full screen on the tabletop prevents people reading ahead, but there is still a problem of deciding when to proceed. Having a simple single button is not enough because it is easy to accidentally press it causing a disruption for the whole group. A safer method is needed, for example a button similar to the ones that can be found on lock screens on a smartphones. At the same time we want the group to agree to move on, and allow submissive users to halt that progress if they feel the need to add something, that is not always so easy to do if a dominant user is a bout to push forward. We decided to combine this need of a slower button with a group consensus by putting one button at each corner, and requiring all four to be pressed to proceed.

Figure 37

First the button is in the state shown on the left (Figure 37), meaning that the current module is not yet complete and the group can only exit. If they press this exit-button it turns orange and starts rotating to indicate that it has been enabled, if all corner buttons becomes enabled the module exists to the overview, but does not unlock the next module.

When a module becomes complete, for example all target areas have been filled with traits, the button changes to number 3 shown in the picture, signifying that the module can be completed. If tapped it turns to number 4, and if all corner buttons reach this state the module exists, is marked as complete and the next module unlocks.

9.4.3.9.2 Result

This mechanic worked well, the users quickly figured out how to use it. No one used the exit mechanic to go back to any module, but it is important functionality if someone enters the wrong module by mistake.

9.4.3.10 Module Overview

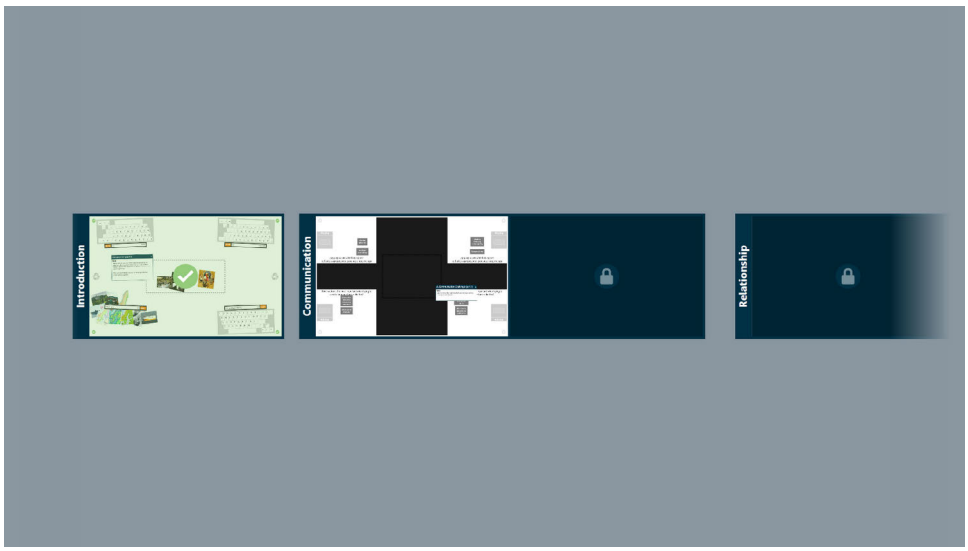


Figure 38

9.4.3.10.1 Description

In the previous iteration and user test the only way to move between modules was to press a custom button on the keyboard. For this version we wanted to test both the corner buttons mentioned before but also provide some kind of overview between the modules. The paper mat provides a custom layout with modules close to different users, due to time constraints we went with a simple scroll view putting modules next to each other in a line in the center (Figure 38). Future modules are locked, the purpose of this is to prevent the group from peeking ahead and wanting to hurry up the current module to reach a more fun-looking one later on. It also eliminates any need to discuss which module to go to next.

9.4.3.10.2 Result

The interface works, the users are able to move between modules, but it could have been designed better. Since it is in the center it is not clear who should tap, and users seem to feel uncomfortable reaching to tap for the whole group. It is also difficult to get a very clear overview of all modules since only 4 can be visible at the same time.

A better design would feature the same kind of layout that appears on the paper mat with all modules visible at all time without scrolling, and a clear user close to the button that is supposed to tap to continue.

9.4.3.11 User feedback

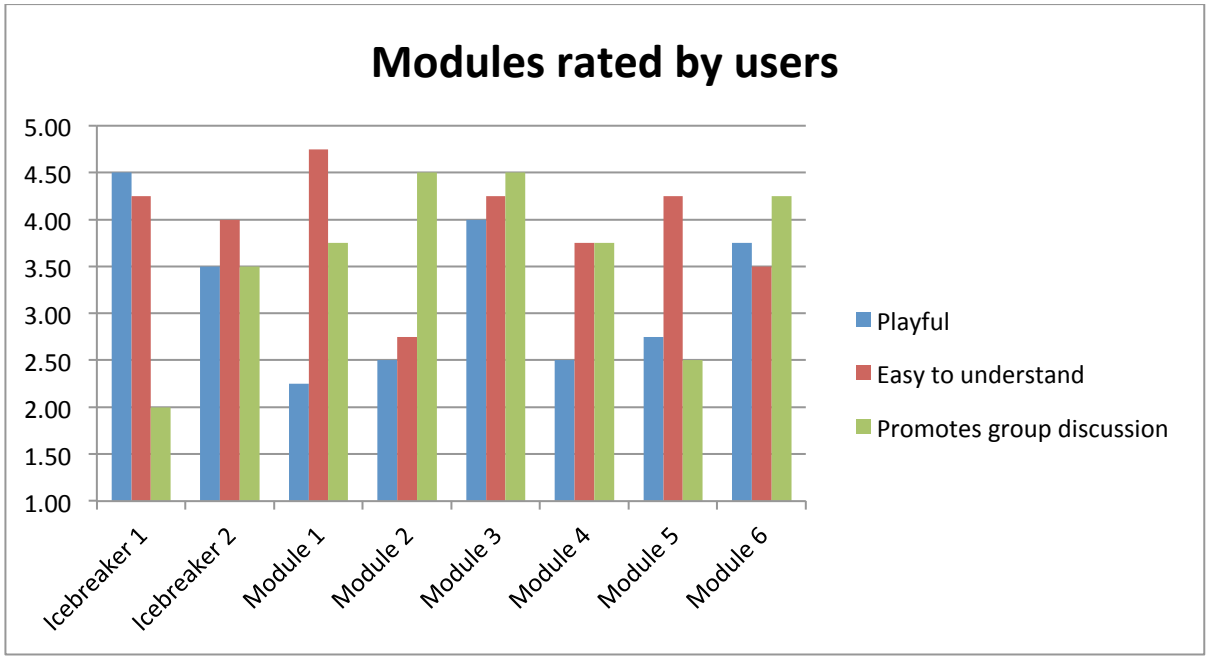


Figure 39

For this second iteration and user test we asked the users to rate each module in three different aspects on a Likert scale from 1 to 5, with 1 being worst and 5 being excellent. The aspects asked about were if the modules are “Playful”, “Easy to understand” and “Promotes group discussion”. The goal being to get an understanding of their personal experiences during the test.

It can be seen that module 3 got the highest combined score (Figure 39), in line with the observations. It is the second most playful module even though it basically just is about dragging pieces of text around. This shows one potential of using a digital table instead of paper, it is possible to not only achieve good discussion through a good question, but also enhance the user experience by augmenting it with a suiting interaction. The paper mat has basically the same question but instead of dragging traits around the person in charge copy them from a table of traits by writing with a pen. It is not feasible to have draggable or movables pieces of items on paper mats for every question, but on a digital table it is not more difficult to have a question in this style than any other.

The first icebreaker was rated very highly on everything except the most important aspect, promoting group discussion. We believe this shows the potential that kind of module can have if a moment of conflict is added. It also shows how much thought has to be put into the content, the actual question and task. The reason many modules work is because of the carefully designed question and task are taken straight from the paper mat; content that have gone through careful design and testing by Specifique. At least as much time should be spent on designing the right questions and content, as on designing the interaction.

Module 1, the very forcing one, has the lowest rating of playful of all. Indicating that this type of module should not be used extensively. Not when modules like number 3 exist which both does a better job of generating discussion and achieve a higher rate of playfulness.

10 General Results & Discussion

The previous chapters contain most of the key points that were discovered during the process. Here we mention a few general observations and design guidelines.

- Design for conflict, avoid effectiveness. Often designers have one goal in mind, make the most efficient experience so that users can become as productive as possible. For example: let users vote on a question to figure out the group consensus. This sparks very little discussion and users keep their underlying reasoning to themselves. The users in both the pre-study observations and user tests did this naturally to avoid conflict and finish as frictionless as possible. On an analog tool it is difficult to prevent users from doing this, but on a tabletop display there are a lot more tools available. A clear benefit of tabletop displays over analog tools.
- The content, i.e. the actual problem or task that the users have to solve is the single biggest factor in sparking discussion. For example, if the answer is too obvious users do not need to discuss. No kind of interaction can fix that.
- Test, test and test. Designing these kind of learning tools is a complex endeavor and predicting human behavior even more so. Adopting a user centered approach with regular user tests is vital to success of this kind of product.

10.1 Mistakes

We attempted to delve too deep into learning territory, something not feasible for two interaction design master students within 30 credits. This lead to a somewhat lost focus, and a too general scope. A much narrower scope with clear defined questions inside the field of Interaction Design could have lead to more definitive and useful results.

We saw that the most useful information came from user tests. Having an even more user centered approach would probably have lead to more insights.

A paper prototype stage or a lighter focus on implementation could have freed up time for more iterations.

Choice of participants. Real end users have learning as a purpose, while all users that were chosen for the user tests had the goal of finishing the mat instead of learning the topic. Real end users might have given more insights.

10.2 Conclusion

The purpose of any thesis should be to try and contribute something back to its field. We believe we have done so in the very specific case of designing a tabletop display DC group learning tool. If someone was to continue this task with the same mission, we believe they would get further if they first read this report. That said, it is difficult to draw any general conclusions based on our work. The

qualitative results we have mentioned should be useful when taken in context, while the quantitative results should be considered carefully before being relied on.

During the previous result and discussion parts we attempt continuously to answer the two research questions posed at the beginning. Here we make a short summary:

What are key design considerations when making a tabletop display, short timespan, Distributed Cognition learning tool?

The results parts of this thesis contain key guidelines and knowledge that attempts to answer this question. They should be able to form a starting point for any future work, i.e. to know in which direction to head.

Does using a digital tabletop display instead of analog tools to support the interaction between users, and between users and external material, benefit or harm Distributed Cognition learning?

Difficult to say anything conclusive, but this limited study seems to indicate, both qualitatively and quantitatively that a digital tabletop display has clear benefits over an analog tool. The tabletop display gives a lot more control over the user experience, and no drawbacks of any kind (that can't be mitigated) were observed.

If the guidelines are followed and the capabilities of the tabletop display are utilized, while adhering to user centered interaction design methods, and at the same time having high quality learning content, it should result in a product superior to the analog version. It simply gives the designer more tools in the toolbox to shape the user experience, in the end it all comes down to how those tools are used. An important point is that the same experience and knowledge about learning that produce good analog tools is still very much needed for digital tools, the core content should not be neglected.

10.3 Future work

Based on the results of this thesis we believe the only logical progression of the field of small group DC learning is towards more digital tools for supporting the process. They give the designer a lot more tools in their toolbox. The only constraints are really financial and technical. Future work could therefor consist of continuing with product development based on the findings in this thesis. To continue investigating the many remaining issues, or to take a step back and rigorously investigate some of the issues that came up.

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