UNIVERSITEIT TWENTE.

Final Project Thesis

Developing a Tool for Learning Concept Maps

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Comparison to other visual mapping techniques

Concept maps are not the only type of visual mapping techniques, ? (?) distinguishes four different types of visual mapping techniques. These types are quite similar to each other, and therefore the differences between them will be elaborated further. Table 1 displays the different types and there specific characteristics.

Novakian concept map

Conditions

Research

Effectiveness

Attitudes

Paired-Associate Learning

Testing Effect

Flashcards

Research

Effectiveness

Student attitudes

Criticism

	Concept map	Mind map	Conceptual diagram
Definition	A top-down diagram showing the relationships between concepts, including cross connections among concepts, and their manifestations	A multicoloured and image-centred, radial diagram that represents semantic or other connections between portions of learned material hierarchically	A systematic depiction of an abstract concept in pre-defined category boxes with specified relationships, typically based on a theory or model
Main function or benefit	To show systematic relationships among sub-concepts relating to one main concept	To show sub-topics of a domain in a creative and seamless manner	To analyse a topic or situation through a proven analytic framework
Macro structure adaptability	Flexible, but always branching out	Somewhat flexible, but always radial	Fixed
Lelvel of difficulty to construct	Medium to high	Low	Medium to high
Extensibility	Limited	Open	Limited
Memorability	Low	Medium to high	Low to medium
Understandability by others	High	Low	Medium

Table 1: A comparison between different concept mapping techniques, as described by ? (?)

Design Choices

Display

Visual mapping technique

As described in section **??** on page **??**, ? (?) distinguishes between four kinds of visual mapping techniques (concept maps, mind maps, conceptual diagrams, and visual metaphors).

Paired-Associate Learning

Design Guidelines

Summary

Part II

Research Proposal

Summary

Here follows a summary of maximum 250 words.

Project Description

Problem Statement

Both the taxonomy of learning proposed by ? (?) as a revision of this taxonomy proposed by ? (?) propose that all learning should start with memorising factual knowledge. This proposition is also entailed within the three stages of skill acquisition by ? (?), of which the first is a declarative stage in which the relevant knowledge is encoded. Finally, ? (?), one of the main founders for critical constructivism, expresses a need for training students so that they permanently possess facts and are able to repeat them flawlessly whenever they are needed, while also understanding what is placed into their memory. The need of students being able to quickly retrieve information at any moment is thereby supported by fundamental educational theory as a prerequisite for further learning and understanding. ? (?) adds to this by stating that in order to perform complex tasks, people must maintain access to large amounts of information, and that solely encoding knowledge is not sufficient. Despite this, ? (?) argues that "[r]etrieval processes, the processes involved in using available cues to actively reconstruct knowledge, have received less attention" (p. 158), whereas basic research on learning and memory has emphasised that retrieval must be considered in any analysis of learning. Therefore, this project aims to research a tool for meaningfully enhancing the retrieval process.

? (?) continues his thesis by stating that meaningful learning often is defined in contrast to rote learning, and that active retrieval is thought of as an example of the latter leading to poorly organised knowledge that lacks coherence and integration. However, in another study they found active retrieval to enhance learning of meaningful educational materials and that these effects are long-lasting, not short-lived (?, ?). In this study, he compared the effects of active retrieval using measures of meaningful learning contrasting to a popular learning strategy known as concept mapping. The latter involves a graph consisting of nodes representing concepts and labeled lines denoting the relation between a pair of nodes (?, ?) (see figure 1). Multiple researchers have found by means of both qualitative and quantitative studies that concept maps can promote meaningful learning leading to positive effects on students (?, ?, ?, ?). This has been demonstrated in comparison to activities such as reading text passages, attending lectures, and participating in class discussions (?, ?, ?). ? (?) describes the process of concept mapping as the only effective way of using the concept map, which refers to students constructing their own concept maps. This is why the concept map is generally viewed as a tool in alignment with the constructivist perspective. Because of this, the concept map might seem as a solution to the need asked by ? (?) and his peers. However, the aforementioned article by ? (?) reveals that retrieval practices produced better performance than elaborative concept mapping for meaningful learning.

One of the currently existing methods for efficiently rote memorising information is the flash-card system, which entails studying declarative knowledge using active retrieval in a so-called paired-associate format. Within this format, learners are asked to associate terms with other

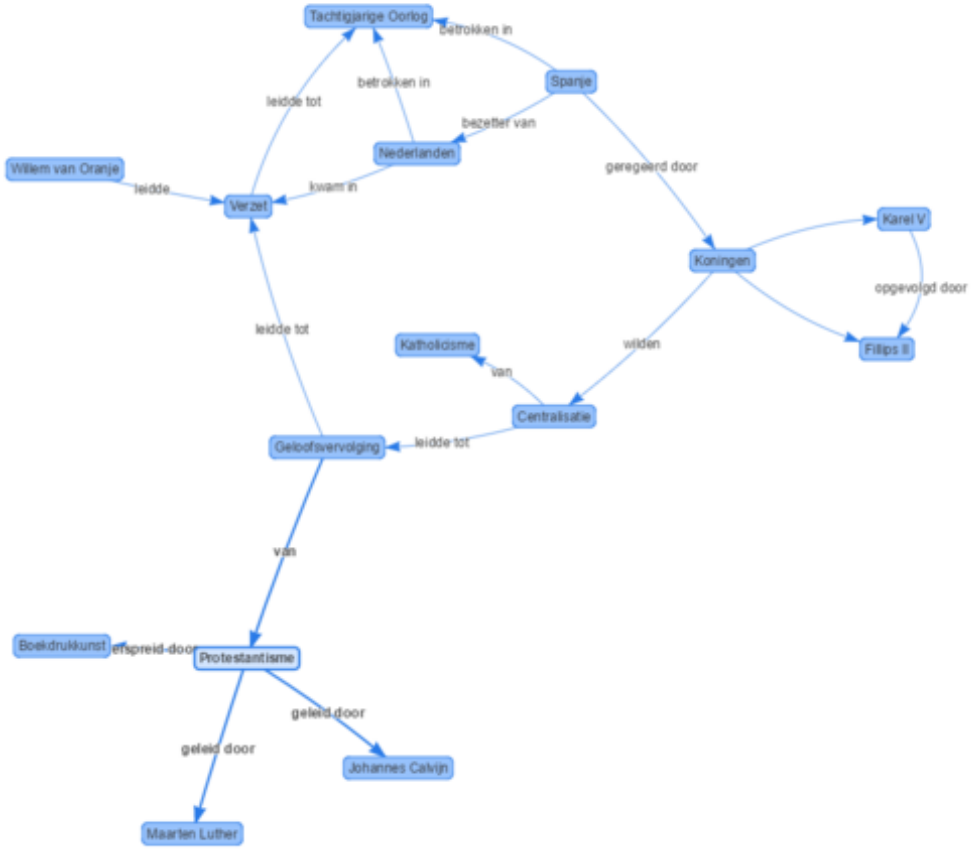

Figure 1: An example of a concept map

terms outside meaning-focused tasks (?, ?), for example by associating a definition with a presented concept. With flashcards, large numbers of words can be memorised in a very short time, and are more resistant to decay (?, ?, ?). ? (?) adds to this by stating that increasing the amount of drill or practice is the most effective device that can be applied to learning. Finally, when evaluating flashcards in a psychology setting, it was found that students who use flashcards have a significantly higher final average than those who do not (?, ?, ?).

Per contra, not all research favours using flashcards for textual comprehension. ? (?) states that flashcards are especially useful for learning declarative knowledge, while learning from a textbook is a form of learning for intellectual skills (?, ?). This problem is also emphasised by ? (?), who states that the use of flashcards is helpful for language learning but the main emphasis of flashcards is memorisation, not comprehension. ? (?) points out the overemphasis placed upon the rote memorisation of disconnected facts, whereas whatever it is that students are to place into memory they should, more importantly, understand. Furthermore, ? (?) describes flashcards as a relic of the old-fashioned behaviourist learning model, and states that we have to look for more modern constructivist models.

Solving the aforementioned problem could lead to better understanding of memory, and could lead to better utilisation by teachers and students with the intent to produce a store of knowledge that remains flexibly retrievable in a variety of contexts over a period of time, in contrast to only segregated paired associations which depend on specific cues in order to be retrieved. Furthermore, it could pave the way for the design of new educational activities based on consideration of retrieval processes. Furthermore, using computer-based flashcards have been used very widely (?, ?), and more recently textbooks have started making flashcards available on their websites (?, ?, ?). ? (?) stated that "Perhaps no memorisation technique is more widely used than flashcards" (p. 125). Improving currently existing flashcards therefore has the potential of reaching a wide audience of future users of flashcard systems. Finally, it might be a solution to the need expressed by ? (?) for more meaningful rote memorisation.

Therefore, another solution might be the development of a new tool, which will from henceforth be refered to as the flashmap system. The intention behind the flashmap system is to combine the paired associate mechanism of the flashcard system with the visual representation of the concept map, and is a new tool designed and developed for this research project. This tool might have the potential to bridge the gap between the two systems and therefore make meaningful and effective rote memorisation possible, for it makes the relations between the concepts explicit to the student and thereby increasing the organisation of the knowledge and reducing the segregation of facts, solving the problems by ? (?) described before.

For evaluating this flashmap system, a group of Dutch highschool teachers of the Stedelijk Lyceum has been found willing to participate, with their students using either the flashmap or the flashcard system for self study parallel with classroom instruction. The content of the instruction will be the history of Dutch literature during the sixteenth and seventeenth century. For example, the students have to learn what the influence is of the Dutch War of Independence on the *Spaanschen Brabander* by Bredero. Because of the content existing mainly of concepts with meaningful relations it fits to the concept map technique and thereby the flashmap system could be significantly beneficial over the flashcard system.

In conclusion, flashcards systems are an effective tool for meaningful learning, but could be enhanced by visualising it with concept maps, and therefore the effects of using a flashmap system over using a flashcard system will be investigated.

Theoretical Conceptual Framework

Flashcards systems

There are many different flashcard systems, varying in scheduling algorithms (?, ?), and offline or online applications (?, ?). The simplest and earliest example is a deck of physical cards, with on one side a question and on the other side the answer to that question. Every day, the student has to go through the deck trying to answer the question on the card. After answering it, the student turns around the card to check whether was correct. If the answer was correct the card goes to the deck for the next day, and if incorrect the card goes to the bottom of the current day's deck.

The main disadvantage of this system is that it becomes time-intensive when more flashcards are introduced, because the student has to go through all of the cards every day. Because of this, newer systems relying on spaced repetition were introduced, with which the time intervals between repetitions increase every time the student answers correctly. ? (?) describes three different types of spaced algorithms, namely progressive, responsive, and adaptive. Within progressive algorithms, the rescheduling of cards are always increasing. Responsive algorithms reset the time interval of a card every time the student makes a mistake. Finally, adaptive systems vary the base increase value of the time interval in order to raise success rates towards a given percentage, meaning that the chance of answering the card correctly is estimated to be equal to that percentage. It was found that the last strategy was more effective and more satisfactory to the user than the other strategies (?, ?).

Furthermore, the transition from physical to digital flashcards is worthwhile to consider. The previously described algorithms can more efficiently be conducted by a computer, since it is able to keep track of a learner's performance and control the sequence of items which can be cumbersome if done manually (?, ?). Furthermore, many students have smartphones with them most of the time, and are more convenient than stacks of traditional flashcards (?, ?). The ownly downside to using digital flashcards is that they are less frequently used than traditional flashcards (?, ?). Reasons for this are technical issues, simply forgetting about it, distraction by entertainment apps and preference for traditional flashcards.

The effects of flashcards have mainly been attributed to the spacing effect (?, ?, ?), which means that repeated items are better remembered when both occurrences are separated by other events or items than when they are presented in immediate succession (?, ?, ?, ?, ?, ?).

Concept maps

According to ? (?), concept maps are defined as hierarchical graphs showing the relationships between concepts, including cross connections among concepts and their manifestations. They also define them by differentiating them from other available visual mapping techniques - mind maps, conceptual diagrams and visual metaphors - by several factors: main function, typical application context, application guidelines, employed graphic elements, reading direction, core design rules or guidelines, macro structure adaptability, level of difficulty, extensibility, memorability, and understandability by others. The function of a concept map is to show systematic relationships among sub-concepts relating to one main concept, without the need for a proven analytic framework or picture. This makes it easy to apply in classroom teaching and self study and a useful support tool for summarising key course topics. The main topic should be placed at the top, so the hierarchy of the concepts is conveyed intuitively. All concepts are represented by boxes or bubbles with text, and the relations by labeled arrows. It is a flexible tool and has a high understandability by others compared to the other techniques. The only downsides are

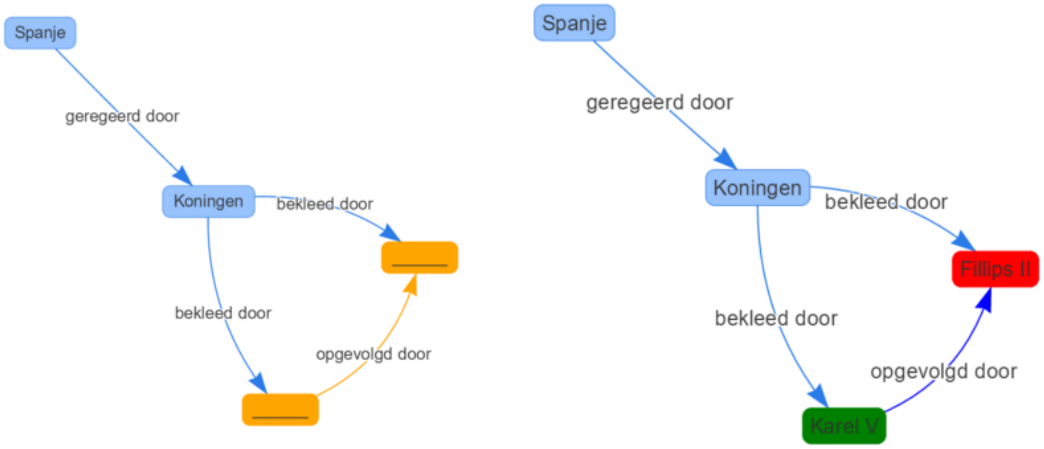

Figure 2: A display of the flashmap system, where the user has to think of the concepts fitting in the orange nodes on the left, and has to indicate which nodes were correct on the right

that it does not necessarily assist memorability, and that it is not easy to apply by novices and requires extensive training.

Flashmaps

The flashmap is intended as an integration between the flashcard system and the concept map. The system uses a predefined concept map constructed by an expert which the users have to rote memorise. Concept maps are chosen here, because it has the best combination of understandability and extensibility. The low memorability is compensated by the flashcard system, and because it is predefined the construction difficulty is taken away. Where a flashcard system would then show a question, the flashmap shows a part of this concept map, where one or more nodes are empty. The user has to think of which concepts would fit in these nodes, and when requesting the answer the flashmaps shows the actual nodes. The student then can indicate per node whether he had it right or not, and they will be rescheduled for review according to the adaptive scheduling algorithm (see figure 2). ? (?) describes that fill-in-the-cmap or memorise the concept map conditions are not recommended, because of the information in memorised concept maps not being integrated with other relevant knowledge and the lack of learners being actively engaged in assimilating new concepts and propositions into their cognitive structures. However, they do not provide statistics or literature in order to support this claim, and furthermore the findings from ? (?) about paired associate learning being more effective for meaningful learning than concept mapping also puts this claim into doubt.

Finally, the flashmap creates the opportunity for a more interactive concept map that starts with a parsimonious and theme-oriented structure which gradually expand the details along with the instruction, which is hypothesised by ? (?) to mitigate map shock. This phenomenon occurs when users view the kind of larger concept maps that might more fully capture textbook knowledge structures, but is a type of cognitive overload that prevents students from effectively processing the concept map and thereby inhibiting their ability to learn from it (?, ?). This mitigation will be facilitated by scheduling the central concepts towards the beginning and the details towards the end.

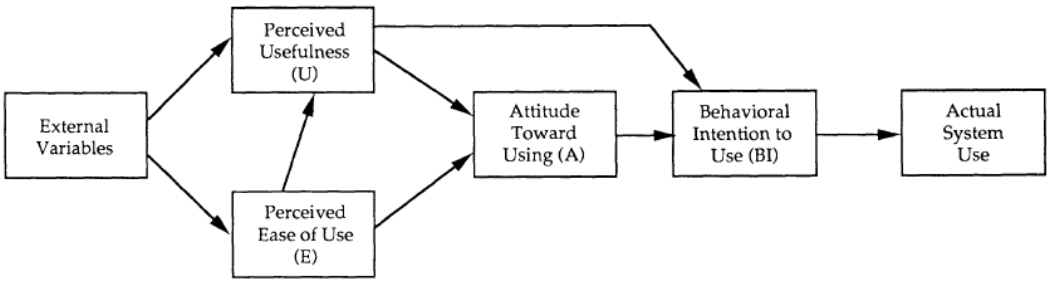

Figure 3: The Technology Acceptance Model by ? (?)

Research Question and Model

For researching the effects of the flashmap system relative to the effects of the flashcard system, it is important to consider two main factors: its actual benefits (research question **??**a and b), and its perceived benefits (research question IIa and b). Furthermore, for the validity of the system and of the experiment it is important to investigate how the system was used by the students (research question III).

To research whether the flashmap system is more effective or efficient than the flashcard system, the learning gain of high school the students will be measured, referring to the knowledge obtained by a student over the course of an instruction. Sequentially, the efficiency of the system is determined by the learning gain controlled for time spend on the system.

For measuring the affectiveness of the systems, the Technology Acceptance Model by ? (?) will be used (see figure 3). This model predicts the use of an information system by measuring the Perceived Usefulness and the Perceived Ease of Use of the user. These variables are mediators between External Variables and Attitude toward using, leading to Behavioural intention to use, which in turn leads to the Actual system use.

Finally, for the answering the final question an interview will be conducted with a sample of the participants, and the server will log information about the user.

This leads to the following research questions: Regarding highschool students learning for Dutch literature using the flashmap system in comparison to them using the flashcard system...

Ia. ...is the learning gain larger?

Ib. ...is the learning gain larger controlled for the time spend with the system?

IIa. ...do they perceive the system to be more useful?

IIb. ...do they perceive the system to be easier to use?

III How did the students use the flashmap or flashcard system?

Scientific and Practical Relevance

Answering the research questions has both practical and scientific relevance. From a practical perspective, it has potential to overcome the criticism from various authors about flashcard systems and answer the need for meaningful rote memorisation. It could furthermore creates new perspectives on the human mind, paving the way for the design of new educational activities based on consideration of retrieval processes (?, ?). From a scientific perspective, it could confirm the hypothesis by ? (?) that an expanding concept map might mitigate map schock. It also makes way for new research opportunities, for example what the effect is of integrating the

flashmap with the games condition formulated by ? (?). Finally, insights could be gained into how digital flashcard systems might be improved for increased use by students.

Research Design and Methods

Research design

Research questions Ia, b, IIa and b will be investigated using intervention-based research. Because of the systems being used for self-study by the students, they can be individually assigned to a condition, and this enables the use of a true experimental design. Since this will provide the most valid and reliable results, this research design is implemented in this experiment.

Furthermore, research question III is a qualitative research question, and therefore an interview will take place after the experiment in order to investigate how the students used the system. Next to the interviews, user data and actions will be logged by the server.

The quantitative and qualitative results will be mixed for the purposes of triangulation and expansion as described by ? (?). The interviews could provide evidence for the systems being used the intended way. Furthermore, by evaluating how the systems were used insight can be gained into why students had certain perceptions on using the systems. Both triangulation and expansion will be on a partial level of mixing, will take place concurrently, and the quantitative data will be dominant, since the qualitative data exists only to triangulate and expand the quantitative data. Expansion will be added within the research question and integrated within the conclusions whereas triangulation will be added within measurement and integrated within the results.

Respondents

More than 100 tenth grade Dutch high school students from the Stedelijk Lyceum in Enschede will be asked to participate in the research. They are concurrent with the experiment, enrolled in a course about 17th century Dutch literature. For this course they already have to prepare themselves for an exam and thereby have incentive to rote memorise the content of the course. To increase the response rate and thereby reduce sampling bias, the students will be rewarded with a bonus point on the exam for participation. In alignment with true experimental design the participant will be assigned to either the flashcard or the flashmap system at random.

Instrumentation

The learning gain will be measured by the means of a pre- and post-test. Both tests will consist of random items from an item bank measuring both knowledge and comprehension levels of the students (?, ?). The tests will be directly based on the concept map, and also will be evaluated by the teacher in order to increase its validity. By using an item bank, the tests will be comparable and thereby the learning gain can be determined by subtracting the score on the pre-test from that on the post-test. Finally the controlled learning gain can be calculated by dividing the

learning gain by the time spent on the system. The survey will be based on the standardised Technology Acceptance Model questionnaire ? (?).

The interviews will be conducted using a topic list (?, ?), including "frequency", "usefulness", "ease of use", "external conditions", and "attitudes", also based on the Technology Acceptance Model. The server logs will contain information about the reaction times, the correct responses, the nodes studied, the time investment, the IP address, and the client, which will be registered per user and per session.

Procedure

An outline of the procedure is given in figure 4.

Before the experiment takes place the experiment will have to be approved by the ethics committee from the University of Twente. After this approval, the students and their parents will be briefed by means of a letter, which consists out of a general description, conditions (voluntary participation and withdrawal at all times), and rewards. They will also both be asked to fill in an informed consent form.

After that, the students with consent will be provided with a general introduction on flashcards by both the teacher and the researcher within the classroom. Then, when the students log into the system for the first time, the server assigns them randomly to either the flashcard or the flashmap condition. By making the introduction ambiguous enough, the students will not be able to recognise this condition in order to guarantee a double-blind experiment.

Before they start using the system they will be asked for general descriptive information such as date of birth and gender. They will not be asked for their names in order to ensure an anonymous identity. Instead a code will be assigned to them making it only able for the teacher to determine the identity. After that the pre-test follows. Then for the next week the students are asked to use the system daily for fifteen minutes. Finally the post-test and survey will be conducted. If the student has used the system for 6 out of 7 days and has filled in the pre- and post-test, they will be awarded with a voucher of € 5. The system will output a list of student codes of those who should be rewarded. At the end of the post-test, the students can also indicate whether they are willing to participate in the interview.

Data Analysis

Research questions Ia, b, IIa, and b will be assessed by means of a t-test, using the following hypotheses:

Ia	H0:	$LG_{fc} \leq LG_{fm}$
	Ha:	$LG_{fc} < LG_{fm}$
Ib	H0:	$LGC(fg) \leq LG_{fm}$
	Ha:	$LGC_{fc} < LG_{fm}$
IIa	H0:	$U_{fc} \leq U_{fm}$
	Ha:	$U_{fc} < U_{fm}$
IIb	H0:	$E_{fc} \leq E_{fm}$
	Ha:	$E_{fc} < E_{fm}$

where LG = learning gain, LGC = controlled learning gain, U = perceived usefulness, E = perceived ease of use, fc = flashcard condition and fm = flashmap condition. For determining the learning gain, the pre- and post-test have to be scored with a predetermined rubric. The answers will be scored without the scorer being aware whether the question was asked within the pre- or the post-test, or which participant filled in the answer. After both the teacher and

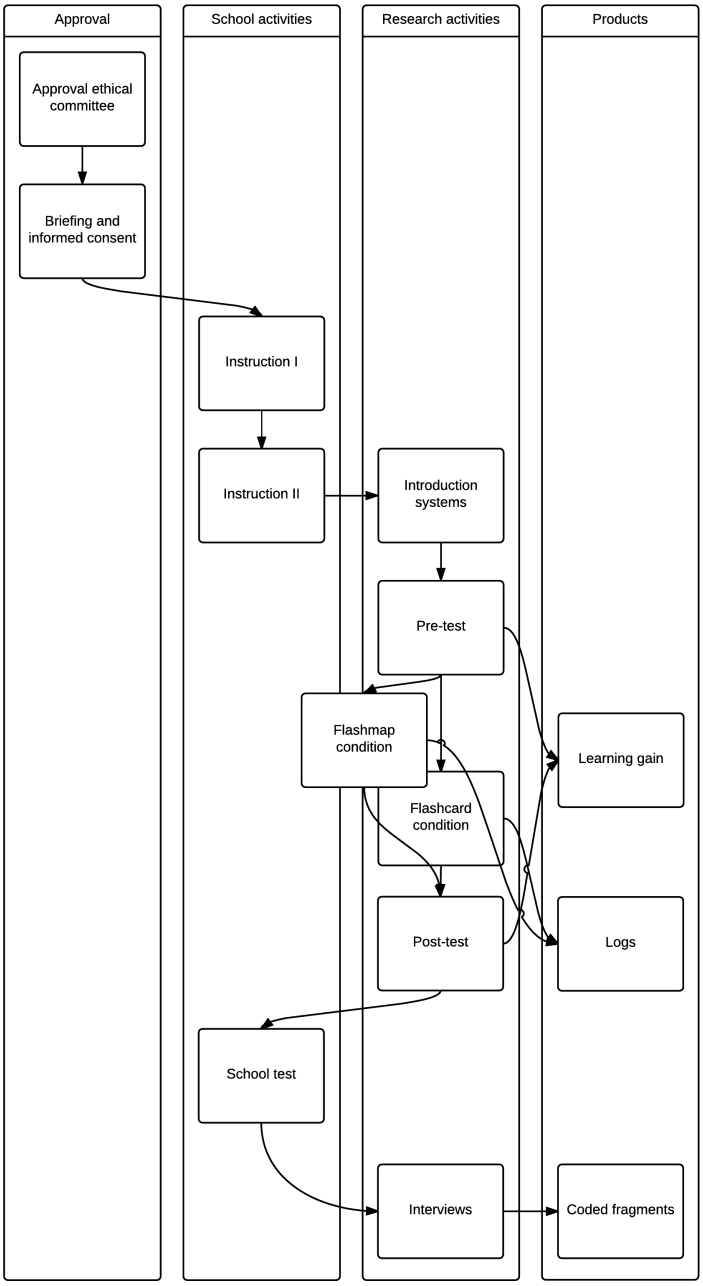

Figure 4: An overview of the different steps conducted within the research procedure

the researcher have scored a sample of the answers, the interrater reliability will be calculated. The rest of the answers will be scored by the researcher only, and after scoring all of the items the reliability of test items will be assessed further using Item Response Theory (?, ?).

The interviews will be transcribed and coded according to ? (?), and another interrater reliability will be determined by a sample of the interviews coded by the researcher and a peer researcher. The coded fragments will be checked to validate the results from the t-tests, together with the server logs made during the experiment.

Planning

Timeline

Outputs