UNIVERSITEIT TWENTE.

FINAL PROJECT THESIS

Developing a Tool for Learning Concept Maps

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Part I

Introduction

Project Description

Over the centuries, knowledge has been fundamental to any learning process. Socrates already stated that knowledge is the only true virtue, and the tragedian Aeschylus regarded memory as the mother of all knowledge. Moreover, it was not only regarded as important by ancient thinkers, but is still regarded as such by modern scholars on education. Both the taxonomy of learning by Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) as a revision of this taxonomy by Krathwohl (2002), as well as the three stages of skill acquisition by J. Anderson (1982), propose that all learning should start with memorising factual knowledge. Furthermore, von Glaserfield (2001), 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. Ericsson and Kintsch (1995) 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 all of this, Karpicke (2012) 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.

Traditionally, when students have to gain complex and meaningful knowledge – for example knowledge about a historical event or a chapter in a psychology textbook, they are asked to read the relevant chapter from a provided textbook. However, Mayer (2008) states that many students have difficulty gaining knowledge in this manner. He breaks reading for comprehension down into four separate skills, which are integrating, organising, elaborating, and monitoring. Integrating refers to relating a text to one's prior knowledge, for which evidence exists that rich background knowledge leads to better inferences about the text, and thereby to better comprehension. This need also has been stressed by Ausubel (1968), and forms different problems between individual readers having access to different background knowledge. After integration, the reader has to organise the text, so that the important ideas and the relationships among them are identified. This is mainly a problem for less experienced readers, possessing fewer strategies to quickly identify important parts and thereby spending too much time on reading unimportant information. While organising a text, the student also has to make necessary inferences while reading, or has to elaborate, which is quite difficult for readers when not prompted to do so. Finally, students have to monitor their comprehension, which refers to evaluating their understanding of the text and if necessary adjusting the reading strategy. This is again quite difficult for the average reader, however this can be trained.

While intergrating is something more dependent on the curriculum design, organising and elaborating can be facilitated by a technique called concept mapping, and monitoring by so-called flashcard systems. Furthermore, the latter might be helpful for the integration of the next topic with the current. This research aims to develop a new tool combining these learning tools. In this chapter, concept mapping, flashcard systems, and the new learning tool called the flashmap will be explored on a practical level in order to establish their definitions together with a summary of arguments in favour or opposition of using them as tools for studying textual material, while also describing their current applications within education.

Concept mapping

A Concept map is a learning tool deviced by Joseph Novak in 1970's, based on constructivist theories of learning. It was originally intended for assessing the structure of student conceptions, before and after instruction, in order to map their prior knowledge and compare it to what they learned during the instruction. This expanded on the notions of Ausubel (1968), who stated that what the learner already knows is most important, and that this had to be ascertained before teaching. Although the use of concept maps as an assessment tool remains prevalent (Cañas & Novak, 2012; Chung, O'Neil Jr., & Herl, 1999; Hwang, Wu, & Ke, 2011; Ruiz-Primo & Shavelson, 1996), over time, students began to use it as a tool to comprehend textual material by organising and elaborating on the included concepts (Cañas & Novak, 2012; Eppler, 2006; Hwang et al., 2011; Karpicke & Blunt, 2011; Nesbit & Adesope, 2006).

Definition

One definition provided by Burdo and O'Dwyer (2015) states that "concept maps are hierarchical representations of knowledge. Construction of them involves linking concepts [...] through the use of linking phrases into propositional statements" (p. 335). The concepts are typically nouns or verbs with or without modifying adjectives or adverbs, and linking phrases specify the relationship between two concepts. Ruiz-Primo and Shavelson (1996) also mention these elements in their own definition, yet Cañas and Novak (2012) and Eppler (2006) include a few extra features, such as the concepts being ordered in hierarchical fashion. They describe two different kinds of links, which are hierarchical links to indicate ranking between the concepts, and crosslinks to indicate relationships between concepts in different segments or domains of the concpt map. The latter would help to see how a concept in one domain of knowledge represented on the map is related to a concept in another part of the knowledge producer, enabling better connections to prior knowledge of the user. According to Eppler (2006), concept maps are always top-down and show systematic relationships among sub-concepts relating to one main concept, however Cañas and Novak (2012) state that they can also be cyclical as long as the concepts still have a conceptual hierarchy. Finally, most of the above mentioned articles describe the links between concepts to be directed. In conclusion, the definition of concept maps used within this thesis will be:

A concept map refers to a directed graph, in which the nodes consist of concepts, and the edges of – either hierarchical or cross- – links labeled with linking phrases, forming several propositional statements about a knowledge domain.

An example of a concept map is displayed in figure 20a.

For this study, the more interesting aspects of concept maps are the use of concept mapping for elaborating, and of demonstrating meaningful relationships between concepts to learners. The first use of the concept map is known as generative use, and the second as supplantive (Smith & Ragan, 2005).

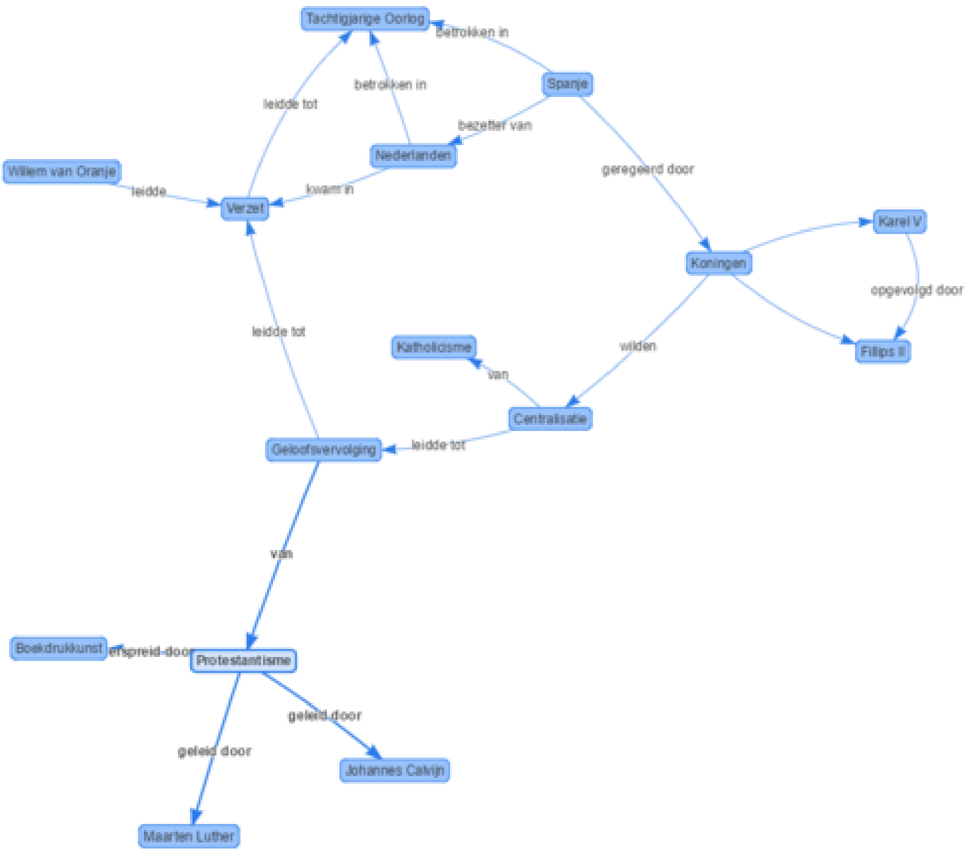


Figure 1: A fraction of the concept map used in this study

Effectiveness

Multiple studies, both qualitative and quantitative, have demonstrated that concept maps can promote meaningful learning (Cañas & Novak, 2012; Hwang et al., 2011; Nesbit & Adesope, 2006; Subramaniam & Esprivalo Harrell, 2015). When comparing the concept mapping strategy with traditional teaching strategies (in a study conducted within the context of tertiary chemistry), Singh and Moono (2015) found that the concept map teaching strategy was more effective, however that it was most effective if both strategies were used in combination. One of the positives of the concept map is that it does not provide learning by means of disconnected facts, but rather as a cohesive narrative placing emphasis on the connections between the concepts. However, most studies state that merely studying a concept map (supplantive use) is not sufficient, and that the activity of constructing the concept map (generative use) is essential for using it as a learning tool. Cañas and Novak (2012) even state that meaningful learning does not work by memorising a concept map, because the information is not integrated with other relevant knowledge. Furthermore, Nesbit and Adesope (2006) state that much of the benefits may be due to greater learner engagement rather than the properties of the concept map as an information medium. However, no studies were found testing these hypotheses, and yet Blankenship and Dansereau (2000) have found that expert generated concept maps are believed to help students form conceptual understanding. Still, this study did also indicate that greater maps (more than 20 nodes) used within textbooks lead to *map-shock*: "a type of cognitive overload that prevents students from effectively processing the concept map, thereby inhibiting their ability to learn from it" (Moore, North, Johri, & Paretti, 2015, p. 3). Finally, Eppler (2006) enlists some of the main advantages and disadvantages in comparison to other visualisation formats (mind maps, conceptual diagrams, and visual metaphors). A positive aspect is that students can gain information rapidly, because of the systematic, proven approach to provide an overview and the emphasis on relationships and connections among concepts. On the other hand, the technique of concept mapping is not easy to apply by novices and requires exstensive training, since otherwise the maps tend to turn out to be idiosyncratic. Furthermore, although better understandability is provided, the overall pattern does not necessarily assist memorability. Finally, the quality of concept maps can be assessed through evaluation rules, however this turns out to be quite a time consuming task for the tutors.

Applications of concept mapping

An article by De Simone (2007) states that despite the effectiveness of concept mapping, its use is not that widespread because students find it cognitively difficult, time consuming, or nonessential vis-à-vis task demands. The article then provides an overview of how concept maps are generally used in the classroom: as an external scratch pad to represent major ideas and their organisation, as a time-efficient tool for mental construction, and as a tool for exchange of diversifying ideas and gaining new insights; and provides benefits and limitations for each of these uses. When used as an external scratch pad, students map their ideas on paper by writing a main idea and linking it with other related concepts through action words and arrows. Although most students find it helpful to offload information externally and detect and correct gaps and inconsistencies in their knowledge, they still find the process of mapping to be time consuming. This is because they often have to make major revisions, requiring them to redraw the concept map multiple times. Therefore, a more time-efficient approach might be mental concept mapping, where they had to represent answers within the map to questions such as "what are the key ideas?" and "how are these ideas related?". This provided to be more efficient due to better mastery of the mapping strategies, and thereby more comfortable for the students. Finally, concept mapping enables students to draw relationships more freely, due to its flexibilities regarding layout and adding or removing concepts or relations. It also stimulated collaborative learning by enabling easier sharing and even co-construction. Nonetheless, of these strategies, the traditional strategy remains the most prevalent, since it is the best known use of concept mapping. Finally, as already stated before, Moore et al. (2015) state that multiple textbook publishers started including concept maps within their textbooks in order to provide an overview of the content.

Flashcard system

In contrast to concept maps, a flashcard system is not intended for meaningful knowledge encoding, but rather for the rehearsal of knowledge so that it keeps active and as such is prevented from being forgotten.

Definition

In the context of language learning, Nakata (2011) defines flashcard systems as learning tools in which "target items are presented outside meaning-focused tasks, and learners are asked to associate the L2 [foreign language] word form with its meaning, usually in the form of a first language translation, L2 synonym, or L2 definition" (p. 17). This form of learning is also referred to as a *paired-associate format*, which refers to learning by being presented by cues and the learner having to recall an associated counterpart. Besides vocabulary learning, it can also be used to memorise word definitions or topographical information. In order to be more inclusive of other use cases, the following general definition is proposed:

A flashcard system refers to any system in which a learner is presented with cues and has to recall their counterparts from a paired-associate format.

The most simple form of a flashcard system is a system where the learner has a stack of cards, with each containing a retrieval cue on one side and the correct associated response on the other side. A learning session then consists of going through the whole stack each day and trying to come up with correct answers. Efficiency can then be increased by repeating difficult cards more often, or skipping reviewing certain easy cards for multiple days. This way only on the pairs which are more needy of retrieval are focused on. Finally, the size of the stack of cards can be increased over multiple days in order to improve the spreading of cognitive load. Next to these paper flashcards, there is also a multitude of digital flashcard systems available (Hwang et al., 2011; Nakata, 2011; Edge, Fitchett, Whitney, & Landay, 2012), which allows for automating the rescheduling of flashcards, providing better access to more advanced algorithms for the rescheduling of flashcards.

Effectiveness

Flashcard systems have not been completely free from criticism by other researchers. Hulstijn (2001) for example describes flashcards as a relic of the old-fashioned behaviourist learning model, and McCullough (1955) states that the main emphasis of flashcards is memorisation, not comprehension. However, Zirkle and Ellis (2010) states that it is still important for teachers and students to understand and utilise memory in such a way that a store of knowledge is produced that remains flexibly retrievable in a variety of contexts over a period of time, even more so because even though it is deemed useless to learn without comprehension, students still should learn by heart many conventional facts (von Glaserfield, 2001). Flashcards have been found to be both a time efficient tool for learning large numbers of facts and an effective tool for these facts to be more resistant to decay in comparison to traditional teaching methods (Nakata, 2011). Their effectiveness also has been demonstrated accross studies in different contexts, for example that of language learning (Chien, 2015; Macquarrie, Tucker, Burns, & Hartman, 2002; McCullough, 1955; Nakata, 2011), word recognition (Joseph, Eveleigh, Konrad, Neef, & Volpe, 2012), psychology courses (Burgess & Murray, 2014; Golding, Wasarhaley, & Fletcher, 2012), and geography (Zirkle & Ellis, 2010). Therefore, many authors support pursuing research into flashcards and its effective application into classrooms.

Design features

Nakata (2011) also describes general design features of flashcard software, which are seperated in terms of creation and editing of flashcards, and learning of flashcards. Examples are whether learners are able to create their own flashcards or flashcard sets, whether learners merely have to recall an answer or have to produce an answer, how big a learning session is and how repetitions are scheduled. Partly, these features are also applicable on paper flashcards. The features will be further elaborated later on page INSERT REFERENCE TO DESIGN CHAPTER, but for now it is sufficient to state that at the time of writing there are no commonly accepted guidelines for how flaschard software should be designed. This mainly is due to the fact that not a lot of research is conducted on specific design-features, because of research reviewing mostly the same program, and there being discrepancies in the way they are designed. Therefore, further research is necessary in order to establish these guidelines.

Application of flashcards

Multiple sources describe an increase in the use of flashcards in education: Kornell and Bjork (2008) states that “perhaps no memorisation technique is more widely used than flashcards” (p. 125), and more recently textbooks have also started making them available (Burgess & Murray, 2014; Golding et al., 2012). Two reasons for the popularity of flashcards are provided by Golding et al. (2012): students can generate flashcards for themselves, they feel that they are ‘doing’ something when they study. Most of the studies found are based around flashcard usage in language courses (Nakata, 2011; Joseph et al., 2012; Chien, 2015), but there also exists a study by Golding et al. (2012) describing that 70% of general psychology students used flashcards for at least one exam.

Chien (2015) and Nakata (2011) describe that multimedia and digital flashcards are used widely within vocabulary learning, because they can be easily programmed to keep track of performance and better control the sequency, which is cumbersome if done manually. Furthermore, students might be more motivated using digital flashcards because of the enhanced presentation of materials due to their multimedia capabilities. However, Golding et al. (2012) still found the majority of students using written flashcards. These findings surprised Burgess and Murray (2014), since many students have their smart phones with them most of the time – 75% of students report using smartphones during breaks, meetings etc, 55% while waiting, and 45% for school related uses – and phones are more portable than large stacks of traditional flashcards. However, when he pursued the study by providing students with either written or digital flashcards, students used the digital flashcards less frequently than the traditional flashcards, even when the students had to make their own flashcards. Reasons students provided were technical issues such as battery consumption, simply forgetting about it, using entertainment apps instead of studying, and preference for traditional flashcards.

Comparison of the two tools

In summary, most studies describe concept mapping as a tool for meaningful encoding, whereas flashcards are described as a tool for rote memorisation, and therefore imply that the former approach leads to more comprehension than the latter. A recent study by Karpicke and Blunt (2011) researched this hypothesis by having participants study a science text with four different learning conditions and prompting them afterwards with verbatim and inference questions and metacognitive predictions. Within the first condition, students only had to read the text and then answer the quesions. The second group studied the text in four consecutive study periods. Students within the third group studied the text in one initial study period and then created a concept map after being instructed in concept mapping. The final group studied the text in an initial study period and then had to recall as much as they could on a free recall test, and repeated this strategy. The time spent on concept mapping and recalling was equal. When analysing the results, it was found that the retrieval practice group performed highest on both the verbatim and the inference questions, whereas the repeated study and concept mapping groups performed about equally well and the study once group performed the worst. Interestingly enough, the retrieval practice group judged their own learning the lowest, and the repeated study group the highest. The same effect of concept mapping and retrieval practice was found again in a second reproduction study, and also in another study by Burdo and O'Dwyer (2015). It is theorised that during elaboration, subjects attain detailed representations of encoded knowledge by linking concepts together in meaningful ways, but that during retrieval, subjects use retrieval cues to reconstruct meaning en thereby already organise the content in a meaningful way. Karpicke and Blunt (2011) conclude that these insights could pave the way for the design of new educational activities with retrieval practices in mind.

Flashmap system

It can be concluded that both of these tools are helpful for studying, since concept maps help students organise by drawing hierarchical links and elaborate on the content by drawing cross-links, and flashcards help students monitor their understanding of the text and retain the knowledge in order to facilitate integration with a following topic where the knowledge may prove relevant. The object of this study is therefore to create a new learning tool, and intends to combine both the visual overview of concept maps with the retrieval mechanism of flashcard systems by means of a new digital tool, which from this point onwards will be referred to as the Flashmap system. It will present incomplete parts of a concept map, in which the student has to fill in the missing parts of propositions represented by that map (see figure 2). These parts will consecutively be repeated according to algorithms already used by digital flashcard systems. The flashmap system might have the potential to bridge the gap between the two systems, and therefore make meaningful and effective rote memorisation possible, for it should make the relations between the concepts explicit to the student, thereby increasing the organisation of the knowledge and reducing the segregation of facts. Hereby, this tool might facilitate the needs stressed by both Karpicke (2012) and Zirkle and Ellis (2010) of more meaningful retrieval. Furthermore, by having the students memorise the concept map and graduately expanding on it, the generally experienced map shock occuring with expert-generated concept maps might also be mitigated (see also Tzeng, 2010).

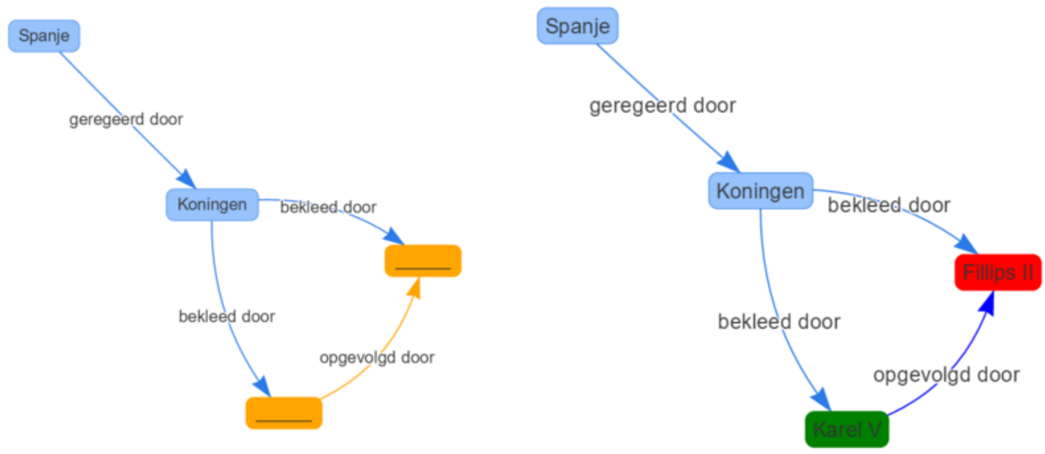


Figure 2: A display of the flashmap system, where the user has to think of the concepts fitting in the orange nodes on the left, and has to indicate which nodes were correct on the right

Evaluation

This project does not only aim to develop a flashmap system, but also to evaluate it by comparing it to a similarly functioning flashcard system. For evaluating this flashmap system, a group of Dutch high school 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.

The research aims to investigate the following questions: Regarding high school 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?

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 Ia 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 Davis,

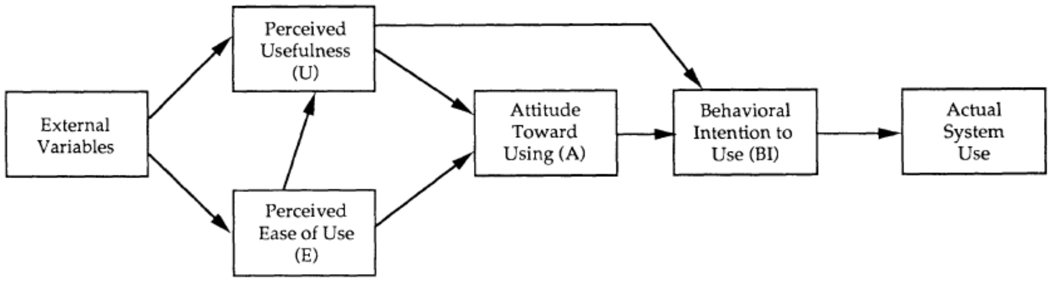


Figure 3: The Technology Acceptance Model by Davis et al. (1989)

Bagozzi, and Warshaw (1989) 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 by the server logging usage information about the user.

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. From a scientific perspective, it could confirm the hypothesis by Tzeng (2010) that an expanding concept map might mitigate map shock. It also makes way for new research opportunities, for example what the effect is of integrating the flashmap with the games condition formulated by Cañas and Novak (2012).

The following chapterwill elaborate further on the cognitive theories underlying concept mapping and flaschard systems on page 15, after which the design and development of the flashmap will be described in part II. The research conducted within this project and its results will be described in part III, and finally part IV will be elaborating on additional features of the flashmap system and how these could be evaluated by further research.

Cognitive theories

This chapter aims to explain the effectivity and inner workings of both concept mapping and flashcard systems by elaborating on the physiology of the relevant parts of the brain, and the relevant cognitive theories. It is important however that these theories mainly focus on a certain type of learning only. According to Squire (1987), there are multiple varieties of memory, which can mainly be categorised into declarative and nondeclarative knowledge, sometimes also referred to as respectively explicit and implicit knowledge J. Anderson (2015). Declarative knowledge also refers to memories that can be explicitly recalled, entailing facts such as definitions, paired associations etc., but also the events where these facts were acquired. Nondeclarative memory involves every memory which can be demonstrated in action, but not in conscious recall per se. Subcategories of these memories are procedural skills, priming, conditioning, and nonassociative memories. Because of the nature of this study, the cognitive theories discussed below are mainly focused on declarative knowledge, although most theories also are relevant to nondeclarative memory in some degree.

Furthermore, Smith and Ragan (2005) describes declarative knowledge as one of Gagné's types of learning outcomes, and relates declarative knowledge to Bloom's levels of recall and understanding, meaning that declarative knowledge does not only encompass rote memorisation of facts, but also understanding the meaning behind this fact. This is also in line with the essay written by von Glaserfield (2001) on radical constructivism, in which it is stated that whatever it is that students are to place into memory they should also understand. Another category of learning outcomes applicable to this context is that of intellectual skills, mainly that of concepts. These, according to Smith and Ragan (2005), help the learners simplify the world and can make them into more efficient thinkers. From a cognitive perspective however, there is not a great difference in dealing with declarative knowledge or concepts, because both relate to explicitly recallable memories and thereby can both be considered as being explicit (Squire, 1987).

Storage and retrieval

Although the whole brain is involved in storing memories, the most prominent areas facilitating the process of memorising are the frontal lobes, medial septum and the hippocampus (J. Anderson, 2015) (see figure 4). The prefrontal regions are responsible for the creation and retrieval of memories, whereas the hippocampal and surrounding areas allow permanent storage of these memories. Because of this dynamic, Atkinson and Shiffrin (1968) conceived a modal theory of memory, displayed in figure 5. In this model, information is perceived as sensory input, and is then shortly stored in the sensory memory. If the perceiver has paid enough attention to the input, it is then transfered (or encoded) into short-term memory. When the input is strong enough, that is, rehearsed often enough within short term memory, it can be more permanently stored in long-term memory. If not, the input fades away from memory and is forgotten. When a

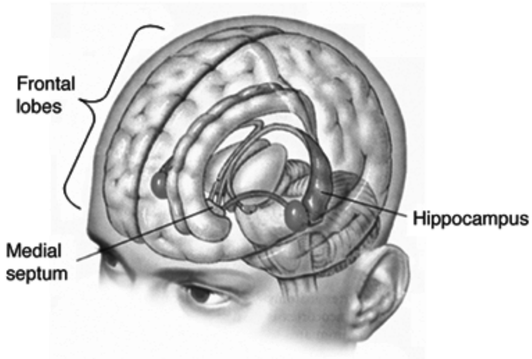


Figure 4: The brain areas mainly involved in storing and retrieving declarative knowledge (A. White, 2003)

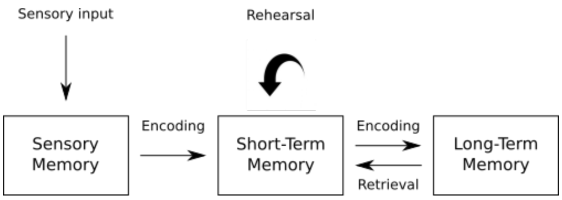


Figure 5: The modal model of memory proposed by Atkinson and Shiffrin (1968)

memory exists in long-term memory, it has to be retrieved into short-term memory in order to be remembered and used.

This model was heavily influenced by developments in electrical engineering and computer sciences, and can be thought of as functioning like a complex computer, where data is written on a hard drive (the long-term memory), and can be used by first retrieving it into working memory (or short-term memory) and later be transferred to the hard drive again (although within a computer the separation is much more clear, whereas short- and long-term memory might overlap more). However, the way the brain works is different from a computer in the sense that a brain has to put effort into memorising data, and that a brain forgets data over time. Therefore, instead of merely inputting the data, learning requires a more rigid approach.

Karpicke (2012) describes two seperate learning practices based on the modal model of memory, namely encoding and retrieval practices, where encoding practices are focused on meaningful encoding or construction of knowledge, and retrieval practiced are more focused on the reconstruction and rehearsal of knowledge. He states that both practices are essential to enhancing learning. Flashcards are a famous retrieval practice, which emphasise drilling the same pairs by association over and over again, whereas concept maps are known to be an encoding practice where the student has to connect diverse concepts within one topic by meaningful relations.

The following sections will elaborate on cognitive effects with regard to both encoding and retrieval practices, and relating them with their relevance to the effectiveness of concept mapping and flashcard systems respectively.

Cognitive effects with regard to encoding practices

The first step of memorisation is always encoding, because (logically speaking) a stimulus first has to be processed and encoded in either short-term or long-term memory in order to be retrieved or used later on. After all, one cannot retrieve a memory which is not already there. It therefore is important to first acknowledge by which means knowledge is encoded, and in what kind of structure it is then stored.

Early metaphors for the brain

For centuries, a lot of metaphors describing memory depicted the brain as a room in which a person could store physical things, for example as a library filled with books or a storehouse with items (Roediger, 1980). This metaphor seems intuitive and is easy to understand, hence it is still prevalent today. There even exists a widely-used memorisation technique called the *loci method*, which lets students are asked to imagine a house where they have to store memories as physical objects in the room. They can then later retrieve the memories by walking through the house along the objects they have stored the memories in (J. Anderson, 2015).

Yet, this model still has certain flaws. Firstly, with regards to retrieval practices, it depicts memories as static objects which only have to be stored to be remembered forever, misleading students, teachers and scientists into focusing more on encoding practices than on retrieval practices (Karpicke, 2012). Furthermore, memories are imagined as separate objects, which does not correspond with how memories are encoded in the brain. As a matter of fact, already in the 19th century, Cajal discovered that memories were patterns of electrical neural activity leading to synaptic changes (Bliss & Collingridge, 1993). This enabled another spatial metaphor, namely that of a switchboard, where the synapses were represented by electrical wires (Roediger, 1980). Later on, when the field of computer science begun to emerge, this metaphor transformed to that of a computer, enabling the conception of the modal model of memory. This is already a more useful metaphor than the physical space metaphor, since it is more biologically accurate, and it emphasises the need of communication between certain nodes (encoding and retrieval between the different memory systems).

However, the metaphor of a computer still has its flaws. A computer stores information on certain independent addresses in the form of binary data, and thereby implies that one can store data for later use without any need for comprehension of the data, and that the data can be formatted in any way the user would like to. Yet, the brain is differently structured, which has consequences for succesfull encoding.

The brain as an associative network

Unlike a computer, the brain is not organised into bits with physical addresses, but rather structured as an associative network. This entails the data being stored and retrieved by means of associated peers. In the brain, the neurons function as the nodes, and the synapses function as the edges. When information is encoded, new neurons are marked, and these are connected to other relevant, already marked neurons in the network. When something then has to be retrieved from memory, neurons signal relevant neighbouring neurons in order to activate the relevant parts of the brain. More generally speaking, when stimulated with a retrieval cue, the brain can then use neural pathways to find a corresponding item in the brain. These networks are sometimes referred to as *semantic networks*, and the implication for retrieval as *spreading activation* (J. Anderson, 2015). This effect has also been found on a cognitive level, for example Kintsch, Welsch, Schmalhofer, and Zimny (1990) has found that material is often not literally encoded, but rather as a set of abstract meaning units representing certain associations between concepts.

Elaborative processing

Because information is retrieved in the brain via related nodes and edges in the semantic network, strong neural pathways facilitate the retrieval process. One way of creating these pathways is elaborative processing (Karpicke, 2012; J. Anderson, 2015), which focuses on meaningful processing of the content. Craik and Lockhart (1972) conducted an experiment where students were to freely recall from a list of words after the students had to train the words by one of the following techniques: answering questions about structural details (e.g. is it in capital letters); about phonemical details (e.g. the word rhyming on another word); whether the word fits into a certain category; and whether the word fits in a certain sentence. They found that the more meaningful the task was, the higher the retrieval rate was (so the latter techniques were more effective). The same result was found by Barclay, Bransford, Franks, McCarrell, and Nitsch (1974). Furthermore, research conducted by Nelson (1979) presented students with paired associates that where either semantic or phonetic (in this case rhymes), and students showed a significantly higher recall of semantic associates. These studies demonstrate the importance of meaningful processing for retention.

Implications for concept mapping

Reflecting on the previously described theory of associated networks, it appears that a semantic network is very similar in structure to concept maps, and thereby the maps provide an accurate representation of the way information is retrieved from the brain. For example, Cañas and Novak (2012) states that "the widespread use of concept maps is based on the notion that a concept map is a reflection of the builder's cognitive structure and thus portrays his or her understanding of the domain depicted in the map" (p. 1). Nesbit and Adesope (2006) speculate that because of this, more and better retrieval cues are created when learning from or generating a concept map. Furthermore, a concept map displays the relations between certain concepts, and thereby focuses more on the meaning behind the content, rather than just the content itself.

Cognitive effects with regard to retrieval practices

According to Karpicke (2012), a lot of educational practices have placed an emphasis on finding optimal ways to encode knowledge and experiences, but that retrieval practices have received less attention. Nevertheless, basic research has indicated that retrieval is still important to consider in any analysis of learning. This is mainly due to the fact that information is not stored exactly and indefinitely, but rather that memories are forgotten over time. Two theories have been proposed and debated over explaining why forgetting occurs, namely by interference of other redundant memories and by decay of existing memories.

Interference and Decay

The theory of interference being responsible for forgetting has been demonstrated in an experiment by J. Anderson (1974). The participants were asked to memorise sentences in the form *A <person> is in the <location>*, where sometimes multiple persons where associated with only one location, and some locations with only one person. They found that if a sentence contained locations or persons with multiple associations this had an impact on the recognition time for that sentence,

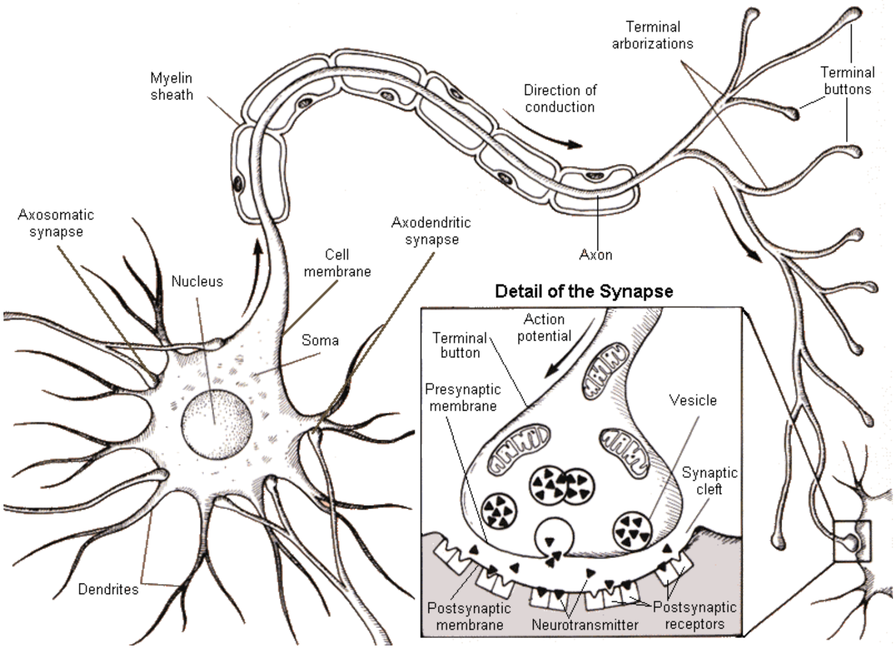


Figure 6: A schematic image of a neuron with a closeup of a synapse (Matsaridis, 2013)

and even more so if both the location and the person had multiple associations. The explanation for this phenomenon is that since memories are retrieved by means of spreading activation and only limited activation can spread from one source (J. Anderson, 2015), the activity has to be divided over different branches in the semantic network, increasing the retrieval difficulty of the correct node. The increase in difficulty is also related to as the *fan effect*.

The effect of decaying memories takes place in the connections between neurons, and therefore it is important to first examine how neurons communicate signals. Figure 6 displays a schematic representation of a neuron in which it can be seen how the soma (cell body) is connected via an axon to the dendritic tree of other cells. The neuron can transmit stimuli by creating an action potential in the nucleus, transmitting this signal through the axon to the terminal button in the connected telodendrion (in the image refered to as the terminal aborization). There, neurotransmitters are released from vesicles, and after they have crossed the synaptic cleft there is a certain chance of being received by postsynaptic receptors. When this is the case, the nucleus of the receiving cell is triggered via the connected dendrite to also create an action potential, and the whole process is repeated (Bliss & Collingridge, 1993). The strength of a certain connection between neurons is therefore dependent on the action potential generated by a nucleus, the amount of telodendria over which the action potential has to be distributed (hence the aforementioned fan effect), the amount of neurotransmitters in the terminal button, and the amount of postsynaptic receptors in the dendrite of the next neuron.

One widely studied effect with regard to the increase and decrease of action potential and strength of memory traces is called long-term potentiation (LTP) (J. Anderson, 2015; Bliss & Collingridge, 1993; Pavlik & Anderson, 2005; A. White, 2003). Whenever a neurotransmitter is received by by a receptor, not only is the next nucleus activated to release its action potential, but also more receptors are activated, so that the postsynaptic membrane is able to receive more neurotransmitters at the next activation. Furthermore, another process is activated altering the metabolical profile of the neuron, causing it to create proteins for more stable increased sensitivity towards stimuli. It is also speculated that there might be a retrograde effect, causing presynaptic modifications such as the creation of more neurotransmitters in the presynaptic vessicles (Bliss & Collingridge, 1993). This all results in an increased sensitivity in the postsynaptic neuron towards action potential in the presynaptic neuron, which then again increases the strength of this particular memory trace. Over time, if a specific neural pathway is not used, the effects of LTP decrease again, causing its strength to decrease and thereby causing decay. This also is a predictor for the *testing effect*, the effect of retrieval strengthening memory more than extra opportunities for further encoding, even when the retrieval is only carried out internally without any outward response (Edge et al., 2012).

Although both the effect of interference and decay have been proposed as separate theories and have been debated, they are still mutually inclusive, and J. Anderson (2015) therefore conludes that forgetting results both from decay and from interference.

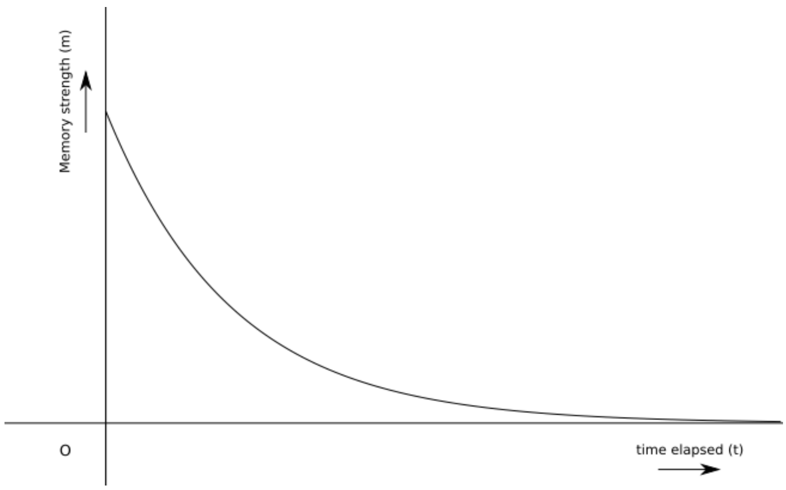
Power laws of forgetting and learning

Now that the relevant theories for learning and forgetting have been discussed, it is important to investigate with which rate people learn and forget. Already in 1885, Ebbinghaus discovered the power law of learning, referred to as the inversal exponential nature of forgetting (Edge et al., 2012; Pavlik & Anderson, 2005). The implication of this model is that memory not only systematically deteriorates with delay, but also that this loss is negatively accelerated, meaning that the rate of change gets smaller with increasing delay (J. Anderson, 2015). Wickelgren (1974) already proposed the formula $m = \lambda(1 + \beta t)^{-\psi}$, where m is memory strength (the probability of recognition), t is time, λ is the state of long-term memory at $t = 0$, ψ is the rate of forgetting, and β is the scaling parameter (see figure 7a). This formula has also found to be accurate by Wixted and Carpenter (2007). Finally, the effect has been directly related to LTP in the rat hippocampus by stimulating neural pathways directly with electrical signals (Raymond & Redman, 2006).

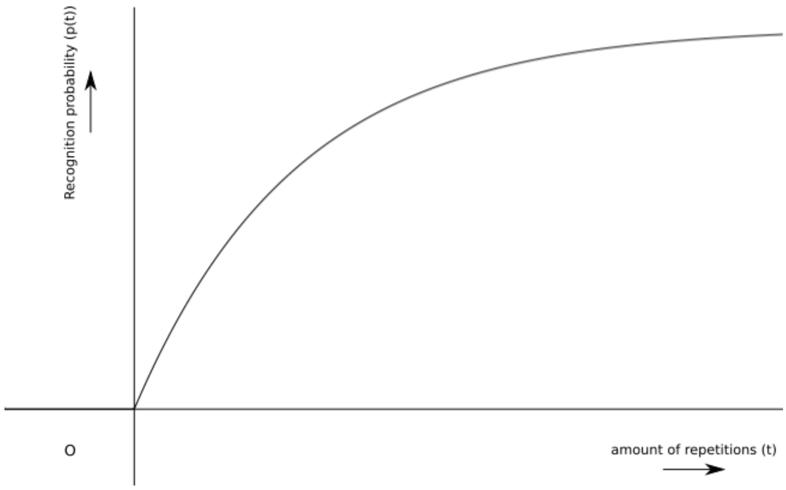
A similar effect has been found for the effectiveness of repetition: Newell and Rosenbloom (1981) have proposed a power law of learning, stating that a learning curve is inversal exponential (see also R. Anderson (2001) and Wixted and Ebessen (1991)). Murre and Chessa (2011) propose $P = p(t) = 1 - e^{-\mu_i t}$ as a function describing this power law, where P or p is the probability of recognition after t iterations and μ is the learning rate of student i (see figure 7b). The power law states that repetition has a positive effect on retrieval probability. This effect however does not increase linearly but inverse exponentially, with an asymptote at a certain amount of repetition. Again, this effect has also been demonstrated in the context of LTP in rat hippocampi (Barnes, 1979). The stronger memory trace from a higher repetition rate does not only result in a higher recall probability, but also in a more gradual retention curve, allowing memories to persist longer.

Spacing effect

The spacing effect is a well known effect occuring within paired-associate learning, and demonstrates that repeated items are better remembered when both occurences are separated by other events or items than when they are presented in immediate succession (Verkoeijen & Delaney, 2008; Logan, Castel, Haber, & Viehman, 2012; Siegel & Kahana, 2014; Xue et al., 2011; Karpicke & Blunt, 2011). This effect has been demonstrated with diverse populations (Verkoeijen & Delaney, 2008; Logan et al., 2012), under various learning conditions (Verkoeijen & Delaney, 2008; Logan et al., 2012), and in both explicit and implicit memory tasks (Verkoeijen & Delaney, 2008). Items in immediate succession are called massed items, and items in separated succession are called spaced items.



(a) The power law of forgetting, with m as the probability of recognition and t as the time passed since learning



(b) The power law of forgetting, with p(t) as the probability of recognition and t as the iterations of learning

Figure 7: The power laws of learning and forgetting

One can test the spacing effect either by using pure lists or mixed lists. When using pure lists, one compares the effect of learning a list containing only massed items with a list containing only spaced items, and using mixed lists one measures the effect of learning both massed items and spaced items in one list, comparing their individual retentions. Verkoeijen and Delaney (2008) state that the vast majority of studies are conducted using mixed lists and found that spaced items were consistently better recalled than massed items, yet studies using pure lists are relatively rare and have produced contradictory outcomes. They conducted a study providing participants first with an all-massed list, then letting them write down as many words as they could remember, and repeat an identical procedure for an all-spaced list with a 2 minute break inbetween. They conducted this experiment with short-lagged spaced items (with 1-4 items in between) and long-lagged spaced items (with 4-13), and found only a spacing effect in the latter experiment. However, Wahlheim, Maddox, and Jacoby (2014) adds to this that repetition is only increases when a student detects the repetition of an item, and therefore the lag should not be too long.

Two theories have been presented explaining this phenomenon, namely the contextual variability theory and the study-phase retrieval theory (Siegel & Kahana, 2014). The first theory entails that because context is not static but continuous, and that therefore spaced items are studied in a greater variety of contexts and as such are easier to recall in yet other contexts than massed items due to the so-called encoding-specificity principle (J. Anderson, 2015). This principle entails that the probability of recalling an item depends on the similarity of the context during the encoding. The study-phase retrieval theory entails that additional retrieval cues for the repetition of an item are generated by earlier occurences and their associated contexts being associated with the repeated item. These theories are not mutually exclusive (Siegel & Kahana, 2014).

Inspired by the power laws of learning and forgetting, Karpicke and Bauernschmidt (2011) conducted an experiment to test the effect of constant or varying lags between items on learning. They tested this by conducting a similar experiment to Verkoeijen and Delaney (2008), however in this experiment they only tested pure lists with three different lag intervals to test for an absolute spacing effect. For each lag interval category they tested for an expanding lag condition (where the lag would increase for the repetition of each next item), an equal lag condition (where the lag would remain constant) and a contracting lag condition (where the lag would decrease for the repetition of each next item) in order to test for a relative spacing effect. From their findings they confirmed the effect of absolute spacing, namely that longer gaps between items do have an effect on long-term retention, yet they did not find a relative spacing effect. However, this has not been tested for spacing with longer intervals, such as intervals spanning multiple days or weeks.

Implications for the flashcard system

It can be concluded that the flashcard system derives its effects mainly from the testing effect by having students actively retrieve information instead of simply encoding it, and from the spacing effect by students going through the items interspersally instead of by immediate succession. The key question however is how often a single card has to be repeated. On the one hand, overlearning can occur, where the student repeats an item too often resulting in diminished learning effects because of the power law of learning, and also only on the short term (Rohrer, Taylor, Pashler, Wixted, & Cepeda, 2005), which is inefficient. On the other hand, if the intervals are too long, students forget the items inbetween intervals, and then the spacing effect does not apply anymore. In order to solve this problem, most modern digital flashcard systems apply a system called *adaptive spaced-repetition learning* (e.g. the Pimsleur system, the Leitner system, Supermemo, and Anki (Edge et al., 2012)). In this system, exponentially expanding intervals are used, not

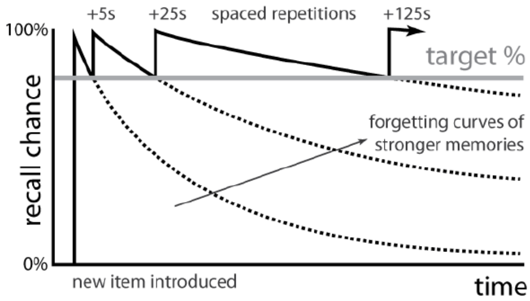


Figure 8: Adaptive spaced-repetition learning (taken from Edge et al. (2012))

because of a relative spacing effect, but rather to increase the average (absolute) spacing with each new repetition. This creates a stronger memory trace every time, but also takes into account the further decreasing risk of forgetting because of the slower declining retention curve (see figure 8).

Conclusion

Overall, this chapter has discussed several cognitive theories related to the storage and retrieval of explicit (or declarative) knowledge in and from the hippocampus. Related to encoding practices, it has now been established that the brain works as an associative or semantic network, and that meaningful or elaborative processing is important for the later retrieval of memories. This seems to fit with the structure and process of concept mapping, although more research is needed in this area. Furthermore, the theories of interference and decay have been discussed in order to explain forgetting of memories, together with Long-Term Potentiation and its effects on the rate of forgetting and learning. In addition, articles were discussed demonstrating that spaced rehearsal is more effective than massed rehearsal. This has finally led to the conclusion that adaptive spaced-repetition learning is an effective method to expand absolute spacing, which entails that items are repeated with exponentially increasing intervals.

Part II

Design Report

The Project Description mainly described the needs which the Flashmap System might be able to accomodate, and on page 12 generic features of such a system is described. Although the term Flashmap System is intended for describing any system including these features, when having to evaluate the idea one has to evaluate one or multiple specific implementations of that idea. Therefore this part will specify the design features of the specific tool developed within this project, along with arguments in favour of and against these choices and their considerations, and the process with which they are incorporated within the tool itself. This description will follow the different steps of the Generic Model (Plomp, Feteris, & Pieters, 1992), which is displayed in figure 9.

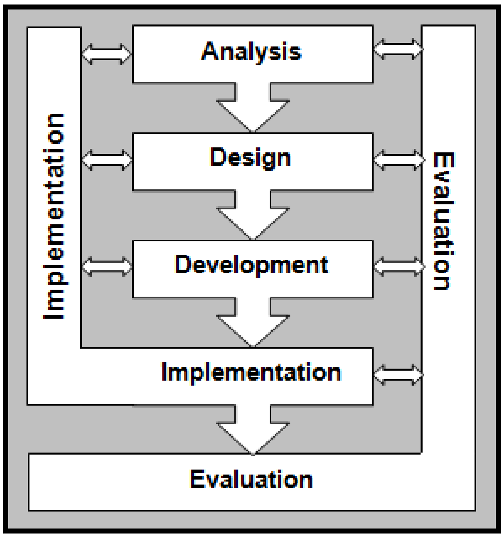


Figure 9: The generic model by Plomp et al. (1992)

The first step consists of analysing the context, learner and task characteristics in order derive their possibilities and requirements. Based on these together with general design guidelines provided by educational literature, design choices can be made and argued for within the next step. When these choices have been made, they can be developed and incorporated within the product. When the product then is finished it can be implemented within the context and evaluated. As can be seen in the model, the implementation and evaluation play an important part throughout the design process, rather than them being seperate steps at the end, and will therefore already be addressed during the description of the first three steps. Furthermore, these seperate steps will be described in the next part, which describes the research conducted within this project. Finally, rather than addressing the design and development in seperate chapters, they will be described alongside each other within the chapters describing the separate facets of the product. INSERT SEPARATE FACETS OF THE PRODUCT

Analyses

Before designing an educational product, it is important that the designer first acquaints himself with the extrinsic factors important to this product. In order to discover the important characteristics of these factors, Smith and Ragan (2005) enlist three types of analyses to be conducted, together with steps for conducting them. These are an analysis of the context, of the learner, and of the learning task. Although these analyses are more targeted towards instructional design, and therefore more focused on a specific group being taught specific content, these analyses will still provide relevant information for the design choices and the evaluation. However, the steps will be adjusted and generalised or even omitted in order to fit the design of the more generic learning tool. The information gathered in order to conduct these analyses mainly stems from meetings with one of the teachers. This might not be the most reliable source of information because of the lack of triangulation, and should therefore not be taken as insight in the curriculum of Dutch Literature courses in secondary education, but rather as context information relevant to the design.

Analysis of the learning context

As already stated in the Evaluation section on page 13, the evaluation of the flashmap system will be evaluated within the Dutch secondary school Stedelijk Lyceum, with students having to learn about the Renaissance genres in Dutch Literature. Although the general needs for a flashmap system are already described in the Project Description, it is still important to investigate the specific needs of the context where the programm will be implemented. Therefore, this context will be further investigated within this section, starting with the Needs Assessment (Smith & Ragan, 2005).

Needs assessment

According to Smith and Ragan (2005), the first step in a needs assessment is to assess whether there is a problem, and what the nature of the problem is (see figure 10), mostly to identify the problem, but also in order to assess whether the innovation model or the discrepancy model applies for determining the needs. The first step is to assess whether there really is a problem in order to establish the general need. During the meetings, the teacher did confirm the need for better retention and comprehension of the content, and indicated that most of the time the students only learned the night before the exam in order to get a high (enough) grade and consequently forget everything again. This is not only wasteful of the effort of learning, but also causes problems when the knowledge becomes relevant again in the next chapter. The cause of this problem therefore definitely lies within the learning process, and could possibly be improved by the use of a flashcard or flashmap system, so it can be concluded that there is indeed a problem caused by learning, and it is thereby useful to proceed with the next phase of

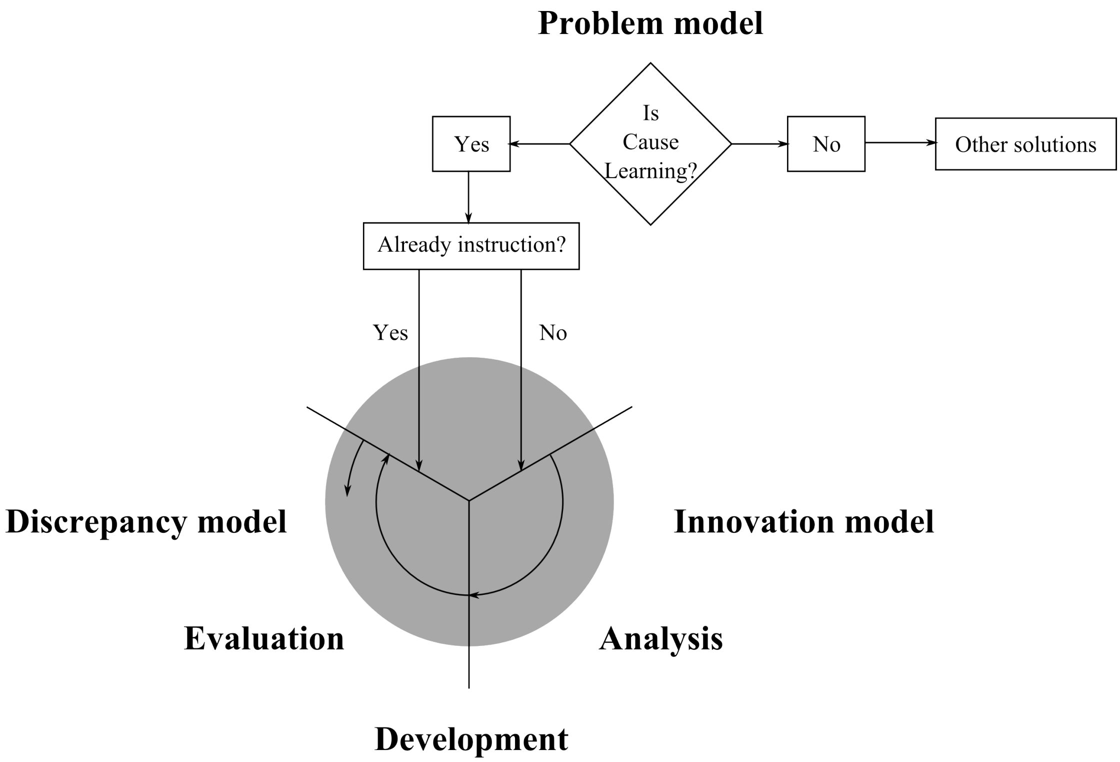


Figure 10: The three sides of needs assessment (Smith & Ragan, 2005)

the assessment. Finally, Smith and Ragan (2005) state that if there already exists instruction for the relevant learning goals, one has to proceed by using the discrepancy model, and otherwise by using the innovation model. The new tool is only there to enhance the current learning process by adding an additional activity, rather than adding new learning goals to an empty space in the curriculum. Thereby, from an instructional perspecticve, the flashcard or flashmap system is only an improvement of the currently existing instructional activities rather than a new innovation, and therefore the discrepancy model will be used.

As can be seen in figure 10, the discrepancy model for needs assessment uses evaluative methods rather than analytical in order to establish the needs within the organisation. These methods include establishing the goals of the instructional system, determining how well these goals are currently being achieved, determining the gaps, prioritising the gaps, and determining which gaps are instructional needs (or in this case, educational needs). These remaining gaps can consecutively be used as a basis for determining the general use cases of the educational product. Normally an instructional designer tries to come into the organisation as a tabula rasa, without any preconceptions on what he would want to achieve and merely try to solve the real problem apparent in the organisation itself. However, because this design is theory driven rather than problem driven, it was merely checked with the teacher whether the problems stated in literature are also a problem here.

The first step was to confirm whether the goal stated by von Glaserfield (2001) of wanting students to memorise many facts in a meaningful way aligned with the goal of the teachers. Upon prompting the contact person what she deemed to be most important for her students to take away from her lessons was for them to become more familiar with the Dutch Renaissance writers or work. For example, she stated that she wanted the students to at least recognise important names when they saw a street name such as the "P.C. Hooftstraat" or the "Vondelpark". She also would like the students to be able to distinguish between different genres of literature, such as the *sonnet* or *emblematiek*. Based on these statements, the goals within the context are in line with students memorising and understanding all of the facts, without them being too ambitious. There are also differences between her and the other two teachers, they namely only offered the materials presented within the books, whereas she offered some additional content which the students also needed to master. However, she also stated that she would be responsible for the extra materials, and that the tool could be only to learn the textbook materials. Finally, she provided a test from the previous year to offer some more concrete examples of what she wanted the students to know, of which an English translation is included in the appendix on page 83. From this test, more goals can be extrapolated, such as students having to not only distinguish different genres, but also to define them or provide characteristics, and recognise the application of these features in both examples of the time periods as well as modern examples. Furthermore, they have to be able to relate the famous writers and writings to the genres.

According to the teacher, the students were mostly able to score points on the reproduction questions, such as having them to provide definitions or enlisting characteristics of genres. Thereby, most students were able to (barely) pass the test, which was already regarded as an important achievement, however minimal it might be. In this regard, the teachers already had scaled down their expectations of the students quite a bit to a realistic and feasible bar. The teacher also tried to make the material more appealing by focusing on examples, with success.

However, as already indicated before, the main problem short retention time due to students learning just before the exam remained an issue for the teacher, and more improvements could be made towards creating an understanding of the content by the students. Furthermore, although the examples make the content more appealing, according to the teacher students generally still did not experience the topic of Dutch renaissance literature as engaging or interesting (see also Heemskerk, 2010). Finally, most of the students would rapidly forget what they have learned after the exam, which the teacher did experience as wasteful. Therefore, the general categories of improvement can be enlisted as the students insufficiently understanding the content, not being immersed or engaged with the content (adequately), and retaining the acquired knowledge for a too short period of time.

Within the context of the Flashmap system, for now only the insufficient comprehension and retention of the content are prioritised, since there is no real evidence within the studied literature that the tool would also make content more immersive (although this could still be a side effect of the tool). These gaps are both instructional needs and are therefore appropriate gaps to tackle within the design.

The learning environment

The school

The Stedelijk Lyceum is one of the two major schools in Enschede (together with the Bonhoeffer College), which has an open denomination and provides education to 3339 students. It consists of 7 minor schools on different locations, of which the Kottenpark location is approached within this project. The location was approved by the Dutch Inspection of Education (*Kwaliteitsonderzoek in het kader van het onderwijsverslag 2016, Het Stedelijk Lyceum - locatie Kottenpark, HAVO, VWO*, 2015) based on analysing relevant documents, visiting the school and observing lessons, conduct interviews with relevant agents (such as teachers and students), and discussing the results with the director and administrator. They reported that the school climate is very positive and safe, and that the teachers have enough professional space to develop themselves. However, they

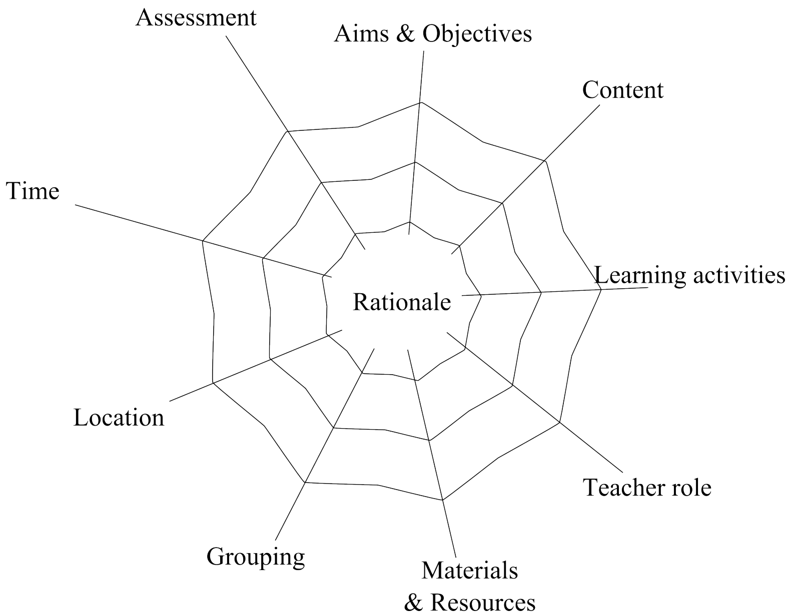


Figure 11: The curricular spiderweb (van den Akker, 2003)

also found that the exam results are some years around the national average, and some years below. The possible reasons they provided were that teachers usually focus on what students have to do instead of what they have to learn, and that they apply differentiation to a lesser extent. Yet, the school now makes use of student monitoring systems, so that they can better tackle problems like language deficiencies and the like.

The curricular spiderweb

Although Smith and Ragan (2005) do enlist some of the steps necessary for describing the learning environment, van den Akker (2003) provides a more widely used and thorough model, and therefore this will be used instead. This model is depicted in figure 11, and displays the relevant components which have to be taken into account for implementation of educational innovations. They are arranged as a spider's web, not only illustrating their many inter-connections, but also underlining the vulnerability of the whole implementation. These aspects will be visited one by one from the perspective of the school, since the learner will be addressed separately in the next section.

The central aspect, *rationale* (or vision), represents the question why students are learning the content in the first place. From the previously visited educational philosophies, one could make many arguments why students should familiarise themselves with Dutch renaissance literature: from a perennialistic or essentialistic perspective one could argue that it is the only way this knowledge can be transferred to the next generation and keeping it relevant; a progressivist could argue that one should first be familiar with older genres before one improve upon them or create new genres; reconstructivists might deem it important since it explains something about the national heritage, and thereby point out the flaws of the old ways; and finally an existentialist sees art in general as a meaningful way for self discovery. This intrinsic motivation is heavily dependent on the individual motivations and philosophy of the teacher. Most of these arguments are represented in diverse Dutch opinion pieces (e.g. Slings, 2007; Dirksen, 2007). In the case of the consulted teacher, the arguments provided seemed to come mainly from the perennialistic and essentialistic perspective, namely that the content is part of our cultural identity and thereby important *an sich*. However, she also indicated the existentialist self-discovery to be valuable. Furthermore, schools are extrinsically motivated to teach the material, since it has to demonstrate to society (mainly the exam committee) that their students have mastered this content. This is mainly related to subdomain E2 and E3 in the Dutch national exam programm, which states that a student can recognise and distinct between literary textgenres, and apply literary concepts in the interpretation of literary work; and that a student can provide the outlines of the (Dutch) literature history, and place literary works in this historical perspective.

Both the content and aims & goals are already stated in the needs assessment, and can be summarised as: Students have to learn about prominent writers and genres within the context of Dutch renaissance literature; have to be able to recognise important names and concepts, be able to define them or relate them to each other, and apply features of genres in examples of texts.

The course consists of two different types of learning activities, which are classroom instruction, and individual learning at home by the students. There are two sessions of classroom instruction, both lasting 50 minutes, in which the 100 students are divided over the three teachers in static groups on separate locations. These lessons take place over the course of two weeks, with one lesson provided in one week. Within these lessons, the teachers transfer knowledge and provide excersises for the students. Outside of the lessons, the students still have to study the textbook Laagland individually (van der Meulen & Kraaijeveld, 2010), which contains all of the materials which will be prompted on a final written assessment. As already stated before, the teacher indicated this activity mostly to take place on the evening before the assessment, and only on a superficial level. Finally, this assessment takes place in the second week after the final instruction, and will be similar to the example test included in the appendix on page V.

The teacher stated that the course mainly consisted of the rote memorisation of facts, and that she was still doubtful whether the students would actually be willing to participate in the evaluation of the Flashmap system. Yet, she did see the general use of the tool for achieving the learning goals, and therefore still seemed to be enthusiastic in cooperation and encouraging the students to participate. The only two technical problems are that there is not too much time for extra activities within the lesson plan and the teachers being quite busy themselves, and that the technological possibilities within the classroom are limited. Within the classroom, only a couple of computers are available for use, and still run relatively old software. Therefore, the activities envolved in using the flashmap have to target the individual learning of students, since they have more time outside of the lesson plan, and mostly do possess the hardware and software necessary to run the software.

Analysis of the learner

In order to tailor to the specific needs and interest of the students themselves, it is important to also investigate the characteristics of the learner. Smith and Ragan (2005) propose a methodology for assessing a learner which focuses on two axes: Stable and Changing, and Similarities and Differences, creating 4 categories. Within these categories, different types of learner characteristics can be distinguished, which are enlisted in table 1. Stable similarities involve characteristics which are similar among people and do not change over time, such as sensory capabilities and their corresponding perceptual responses, the way people process information, and finally the ways and conditions in which people learn. Stable differences relate to characteristics different among people but stable over time, such as certain aptitudes, cognitive styles, psychosocial traits, or inheritary traits such as gender, ethnicity & racial group. Changing similarities are similarities that do change over time, these characteristics are mainly attributed towards development processes. Finally, changing differences are differences in development accross people, which can mainly be attributed towards different upbringings or interests. Instead of visiting the learner characteristic according to each above mentioned category, Smith and Ragan (2005) propose a more conveniently arranged outline which will be used in the next sections, albeit slightly altered in order to fit the current project.

	Similarities	Differences
Stable	Sensory Capacities Information processing Types and conditions of learning	Aptitudes Cognitive Styles Psychosocial traits Gender, Ethnicity, & Racial Group
Changing	Development Processes: - Intellectual - Language - Psychosocial - Moral - Other	Developmental state: - Intellectual - Other Prior learning: - General - Specific

Table 1: The four categories of learner characteristics (Smith & Ragan, 2005)

Physiological characteristics

The students who will participate in the research are enrolled in grade 4 of Dutch secondary education, and therefore should be around the age of 16-17, with some deviations due to students either having skipped or repeated a grade. Therefore, the students are generally considered to be either at the end of puberty, or the beginning of young adolescence. The Cognitive theories chapter on page 15 already provides general theories about the learning process within the brain. However, during late puberty and early adolesence, the brain is still heavily in development, especially the prefrontal cortex. (Blakemore, Burnett, & Dahl, 2010). These changes might be even more relevant than the proper age, and therefore they will have to be elaborated on further before delving into the cognitive characteristics.

In order to map out the changes in the adolescent brain, Giedd et al. (1999) performed a longitudinal MRI study of the brain development during this period, of which the results are displayed in figure 12. Within this study, three themes emerged within the adolescent development of the brain:

1. After a peak in growth of both brain cells, connections and neurotransmitters during childhood, one can see a decline in adolescence;
2. The connectivity between different regions of the brain increases;
3. A new balance is formed among frontal and limbic lobes.

The first theme is a result for the brain becoming more streamlined after having collected a lot of information during late childhood, making it more efficient (see also page 18 on Interference and Decay). This is also known as peak plasticity, after which a decrease can be observed. Powell (2006) describes this phenomenon as *Use it or lose it*, since the brain rigorously selects the specific memories which are activated during this time. The second theme refers to the strengthening of specific memories, which are enhanced during that period. Finally, during adolescence a shift

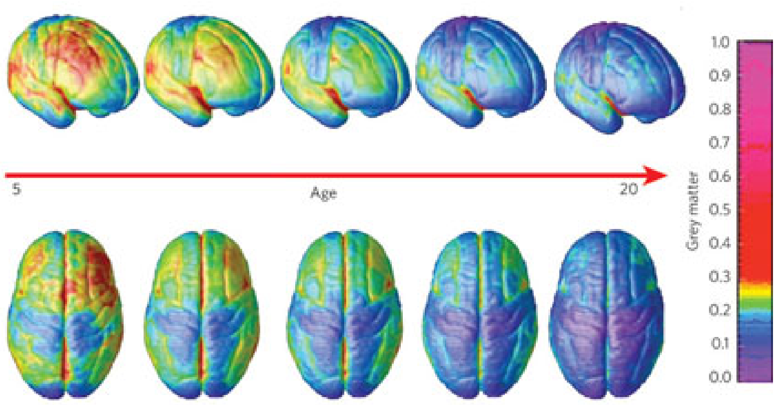


Figure 12: The MRI scans from the longitudinal study conducted by Giedd et al. (1999), showing the maturation of the brain during childhood and adolescence

is made from "cold" to "hot" cognition, where the former relates to hypothetical, low-emotion reactions, and the latter to high arousal decision making, strongly influenced by peer pressure and real, direct consequences. This is highly related to the prefrontal cortex being heavily developed, resulting in the teenage brain to rely more on the amygdala which is the more emotional, impulsive area of the brain.

The developmental level of the prefrontal cortex has also been found to positively correlate with the IQ of students, more so than other regions of the brain, which is an indication of this development to be the most influential for the cognitive development within adolescents. Finally, it has important consequences for the cognitive development of adolescents. They become more capable of abstract, multidimensional, planned and hypothetical thinking in comparison to children (Steinberg, 2005). Adolescents also tend to use their hippocampus more often during the execution of certain tasks (Finn, Sheridan, Hudson Kam, hinshaw, & D'Esposito, 2010).

Cognitive characteristics

The Dutch highschool is subdivided into three main categories, which are VMBO, HAVO and VWO, ranking from lower to higher rates of academic achievement and expectations. The students targeted within this projects are VWO-students, which means that they are most likely to have a relatively high IQ, and are quite apt of learning for and passing written tests. Furthermore, at the beginning of grade 4 of VWO, students are allowed to choose between a nature profile or a society profile, determining whether they have respectively have more STEM subjects (such as math or biology), or subjects more related to language, humanities or economy. Therefore, where students who chose the nature profile are generally more apt to apply logic to technical problems, those who chose the society profile are generally more apt and used to learning information by reading texts. This makes up for different specific aptitudes within this specific Dutch literature course, where reading skills are more relevant. VWO-students are also subdivided into Gymnasium and Atheneum students, where the former group outside of the regular curriculum also has to learn classical languages (Latin and Ancient Greek) and culture. Because the Dutch renaissance literature has a lot of connections with classical genres, Gymnasium students might have an advantage in prior knowledge. Furthermore, all students should have learned about the relevant time period in their history classes prior to this course (e.g. the Spanish War, the Lutheran

Postal code	Number of residents	Number of households	SES score	SES rank
National			0.28	
7521	9555	4624	-1.28	3254
7522	**7100**	**4551**	**-0.37**	**2792**
7523	12180	6060	-1.62	3333

Table 2: Indicators of socioeconomic status on both national and postal code levels (*Statusscores*, 2015)

reformation etc.), providing with the relevant knowledge to understand the context of Dutch renaissance literature. Finally, the students have received a similar instruction on Dutch medieval literature, which is also relvant for concepts in the renaissance literature, such as the *Mecenas*, the *Lyriek* and *Rederijkers*.

Social characteristics

This section covers the stage of moral development, the socioeconomic status, the racial or ethnic background, and the religious denominations of the students. The stage of moral development is relevant since it influences the individual decisions the students are likely to make. The socioeconomic status (SES) is found to influence the academic achievement of students, since they are predictors of both the safety of the home situation and the support from the parents. Furthermore, racial and ethnic backgrounds might influence the attitudes that students have towards certain topics. Finally, since the subject of Dutch renaissance literature is heavily influenced by religion, especially the reformed church, the denomination influences the perspective of the student towards the subject, and determines a certain amount of prior knowledge. The SES, the racial or ethnic background, and the religion have not been investigated within the target group, so instead public available statistics from the Dutch social and cultural plan agency (*Sociaal en Cultureel Planbureau*, SCP), the Ministry of the Interior and Kingdom Relations (*Ministerie van Binnenlandse Zaken en Koninkrijksrelaties*, BZK), and Statistics Netherlands (*Centraal bureau voor de Statistiek*, CBS) were used.

Every four years the SCP publishes data reporting the socioeconomic status (SES) of postal areas in the Netherlands (*Statusscores*, 2015). The SES is based on three variables of the people living there, namely their education, their spendable income, and their position on the labour market. The data about the postal area of the school is displayed in table 2, together with the data of its two major neighbouring postal areas. As one can see, all of the values are below the national average SES, and that the surrounding postal areas have a lower SES than the school's postal area. However, academic achievement and socioeconomic status are highly correlated (K. White, 1982), and given that the approached students are enrolled on the VWO level one might expect them to come from households with higher incomes. Furthermore, the BZK frequently publishes indications of living circumstances (*Leefbaarheidssituatie Buurten Enschede*, 2015), which is specified with smaller areas and is found to correlate with the SES (Knol, 2005). On this map, the area Bolhaar scores a 0.3 in comparison to the national average. It could therefore be that the actual SES of the students of the school is somewhat higher than indicated within the table, especially since there is also a university campus within the same postal area, where low income university students live.

Among other data, the CBS offers descriptives of students, categorised per national district. This descriptive data entails information about the age, sex, type of education, and ethnicity of students, and the interactions among these variables (*Leerlingen, deelnemers en studenten; onderwijssoort, woonregio*, 2016). From this data, descriptives about 16-17 year old students from

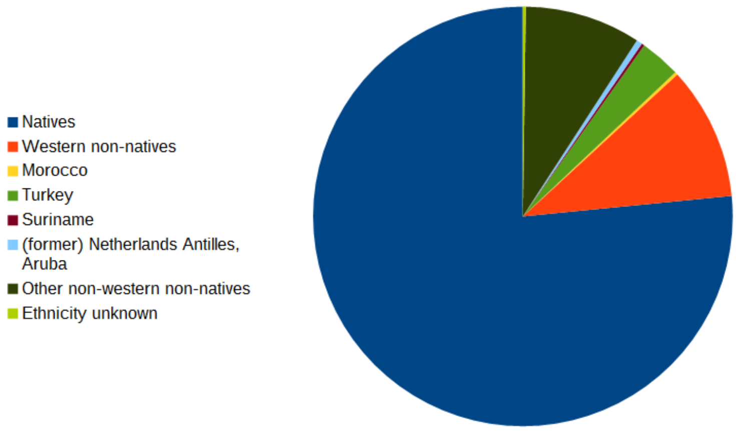


Figure 13: The distribution of ethnicities among 16-17 year old vwo students of education type vwo3-6 (*Leerlingen, deelnemers en studenten; onderwijssoort, woonregio*, 2016)

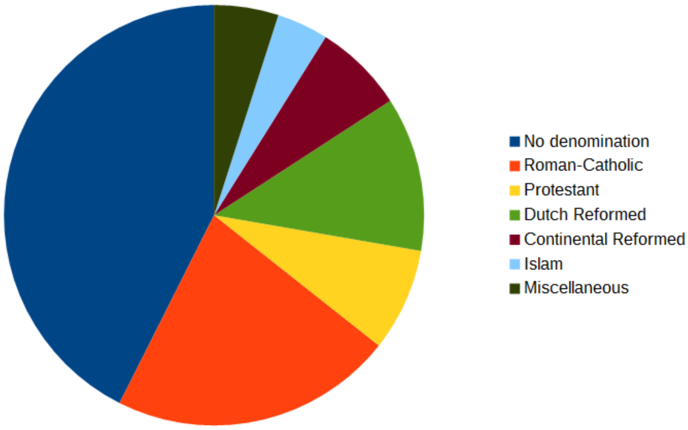
Enschede enrolled in vwo grade 3-6 was extracted, displaying their age and ethnicities. 23% of the 16-17 year old students are enrolled in VWO, where 44% is male and 56% is female. The distribution of ethnicity is visualised in figure 13. 77% of the students are native and 31% are non-native. 9% of the students is western non-native, and 22% is non-western non-native. The CBS defines a non-western non-native is an non-native originating from Afrika, Latin-Amerika and Asia (except for Indonesia and Japan) or Turkey. The most prevalent non-western ethnicity is Turkish, with 8%.

Finally, the CBS also offers statistics about religious denominations (*Religieuze betrokkenheid; kerkelijke gezindte; regio*, 2015), which state that 57% of the people in the province of Overijssel is affiliated to a church. These affiliations are split up in different religions: 22% Roman-Catholic, 8% Protestant, 12% Dutch Reformed, 7% Continental Reformed, 4% Islam, and 5% miscellaneous (see figure 14a. 43% is not affiliated to any church, however this does not necessarily entail that they do not have a religious worldview. Data is also offered on how frequent people visit the church: 14% visits every week or more often, 4% two or three times a month, 4% once a month, 8% less than once a month, and finally 70% (almost) never (see figure 14b. This would indicate that although there is a majority affiliated with a certain church, most of the people do not actively take part in their respective community. There are also more specific statistics available about the region of Twente only (*Religie; naar regio; 2000/2002 of 2003*, 2004), however these are older and might already have changed significantly over the last 13 years. Yet, they state that Twente is more religious than the overal province of Overijssel. Unfortunately, there are no statistics available about Enschede only. Finally, the school of the target group has an open (i.e. non-religious) denomination, whereas the other large school in Enschede has a christian denomination, so one might expect mainly the students without any strong religious views to choose for this school.

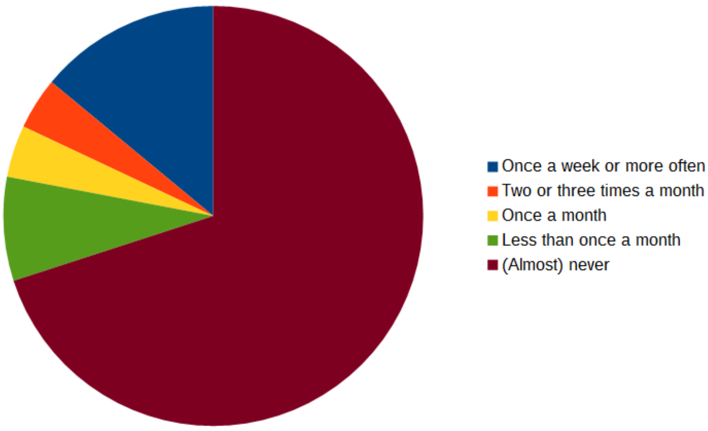
Affective characteristics

The influences on the students attitudes can be mainly categorised into two factors: the natural factors and the nurtural factors, which will be described in seperate paragraphs below.

Within the section Physiological characteristics on page 31 it was already described that students rely mainly on their amygdalic systems instead of their prefrontal cortex during young



(a) A distribution of church affiliations



(b) The distribution of frequencies of church visits within the group of people affiliated to a church

Figure 14: Denominations within the region of Twente (*Religieuze betrokkenheid; kerkelijke gezindte; regio*, 2015)

adolescence. According to Steinberg (2005), this mainly leads to reward-seeking behaviour, peer-reliance, risk-taking, and poor decision making. This has the consequence of students being heavily influenced by the direct consequences of their actions rather than the long-term benefits or drawbacks, which are in a lot of cases related to social rewards and stimuli rather than cognitive rewards. Furthermore, they are more likely to take certain risks in order to gain these rewards, possibly causing procrastination-like behaviour until the risk of failing the exam is too large. This is also heavily related to poor decision making, at least in the long term. These types of behaviour are also in line with what the teacher stated about her students, namely that they postpone their studying behaviours until the last possible moment (in most cases the night before the exam), and that their strategies are not more elaborate than just reading or even skimming through the chapter.

Furthermore, it is useful to involve research on attitudes of the target group towards the task they have to perform. However, no research has been conducted on the attitude of high school students towards Dutch renaissance literature, and research into high school student perspectives on subjects within the Humanities are scarce in general. The most relevant study found was a study conducted by Grever, Pelzer, and Haydn (2011), on the perspectives on learning history by Dutch, English and French high school students. Within this study, students were asked several questions about what kinds of history, which periods of history are important or interesting for the students, and what the meaning of history is for their personal lives and what they believe to be its relevance for society. For Dutch students, this study found that the history of ones own family generally ranks high, and after that the history of the country where the parents come from (both for natives and non-natives). This means that native students might be more interested in learning about the subject than non-native students. Furthermore, the history of ones own religion is mostly important for Moroccan and Turkish students (which are mostly muslim), so the history of christianity is generally not that interesting towards most students. The study also found that the time period of early modern history is the least interesting for students, no matter the gender or nationality, despite that in the Netherlands the most important topic is the rise of the Dutch republic and the Golden Age (the content of the subject used within this study). Finally, the study states that there were no significant differences in perceptions of pre-vocational students and HAVO/VWO students in these respects, although one might expect Gymnasium students to be more interested in the classical revival of art during the renaissance than the Atheneum students.

Analysis of the task

Finally, the characteristics of the task itself will be investigated in order to learn how to design a tool in such a way that it facilitates or augments the learning process. Smith and Ragan (2005) enlist primary steps for performing a learning task analysis, which are writing a learning goal, determining the types of learning of the goal, conducting an information-processing analysis of that goal, conducting a prerequisite analysis and determining the type of learning of the prerequisites, writing the learning objectives for the learning goal and each of the prerequisites, and writing the test specifications. However, within this project the instruction has already been written (van der Meulen & Kraaijeveld, 2010), and only has to be used to create a concept map. Still, knowledge of the underlying structure of the instruction might prove to be helpful for finding the relevant elements, and it is also useful to investigate the specific uses of the instruction within the context of this project.

Learning goals

The direct learning goals of the instruction can be found in paragraph 13.4 of Laagland, the specific instruction for the Dutch renaissance literature, where the previous paragraphs only provide the prerequisite knowledge necessary to understand this paragraph. The different chapters describe the *emblematiek*, the *lyriek*, the sonnet, and the different theatrical genres (the tragedy, the comedy, and the *klucht*). One of the goals of this instruction is that the students are able to describe these genres, and are able to differentiate between the subgenres or terminology within these genres. However, the students also have to be able to relate these genres to the general context described in the previous chapters, which consist out of the political, the socioeconomic, and the cultural backgrounds.

Types of learning

Attaining these skills are mainly intellectual in the typology defined by Smith and Ragan (2005), because the students mainly have to be able to describe and discriminate between defined concepts. However, there is also a certain amount of declarative knowledge learning involved because students have to first learn and memorise certain definitions or conceptual organisations. Furthermore, within the book there are not only abstract concepts being defined, but also declarative knowledge such as names of important authors (Vondel, Bredero etc.), books or plays (e.g. the *Klucht van de koe*), and certain historic events such as the migration of calvinists from Antwerpen to Amsterdam in 1585.

Concept map

Because the information has already been defined within the textbook (both the new content and prerequisite content), the information-processing and prerequisite analysis activities have been replaced by translating the content of the instruction within the textbook to a concept map. Within this map, not only the relevant concepts, names and events are presented, but also the relations between them, providing a more meaningful representation. Furthermore, the concept map also contains information about the order in which the concepts have to be learned, because of the direction of the relations. The data used for the concept map is uploaded on github[1]. A direct visualisation is too extensive to be feasibly included within this report, however a digital visualisation is available[2] (after a short initial rendering time due to its size). The Client design and development chapter on page 65 will elaborate further on the design choices for the concept map. Finally, this map is directly shown to the students within the flashmap condition during the experiment.

Flashcards

The activity of specifying the learning objectives is replaced by formulating the flashcards, because the flashcards already form the specific knowledge-based learning objectives. They already contain the most important types of information which should be included in an objective, namely the statement of the terminal behaviour (the answer itself), the conditions of demonstration (given this question, the student can reproduce the correct associated answer). The standards or criteria for these objectives are globally defined, namely that the student has to be able to demonstrate that he knows the correct concept corresponding to a parent node and edge label. The flashcards are directly based on the previously defined concept map. Within this activity, edges and their

[1] `https://github.com/mcvdenk/MasterThesis-Software/blob/master/database/concept_map.json`
[2] `http://www.mvdenk.com/thesis/concept_map/`

corresponding parent nodes were transformed to a question, and the child node formed the answer to that question. For example, the nodes *Strijdliteratuur* and *Actualiteit*, respectively connected by the edge *verwees naar*, is translated to a flashcard "Q: Waar verwees de Strijdliteratuur naar?" → "A: Naar de actualiteit" (*Translation:* To which did the war literature refer? To actual events). Sometimes, multiple edges from one node to several child nodes having the same label or falling within the same category were translated to only one single flashcard. The data for the flashcards can be found again on github[3].

Test specifications

The assessments conducted before and after the students have used the learning tool consist partly out of the questions from the flashcards for measuring knowledge reproduction, but also partly of questions targeted to measure the comprehension levels of the students (see Bloom et al., 1956). On both assessments for all questions, the students are asked to fill in an answer in a textbox. In order to answer the questions for comprehension, a student has to be able to draw relations between not directly linked nodes, and thereby requires a higher degree of mastery of the content. It does however not yet contain any questions where students have to apply the content within different context, or have to think outside of the content directly taught, since these questions would rate on even higher levels on the taxonomy of Bloom. Finally, the questions are phrased according to the specified action verbs related to the level of learning. A more detailed elaboration of the test construction and analysis can be found in the Instrumentation section on page 72, and all of the comprehension level questions are included on github[4].

Implications for design

From the analyses above, certain conclusions can be drawn for designing the learning tool. First and foremost, the tool should aim to facilitate long-term learning, so that the effort spend both teaching and learning is not wasted due to the students afterwards forgetting the content again. Furthermore, it is important that the students not only memorise the content, but also comprehend it.

The tool also has to be used for self-study only, since the school cannot spend any extra time on using the tool within the curriculum. This means that students are learning individually, whenever and wherever they want to, and are using the tool on a voluntary basis. This creates a more informal but also unstable learning environment.

However, because young adolescents have a heavily developing prefrontal cortex, they experience problems with planning ahead for studying, and are also less motivated to do so because of higher amounts of peer pressure and the like. Furthermore, it was found that the subject that they have to study is less than favourable, since it is about early modern history, and non-western non-natives might even have a lower interest in the rather nationalistic subject. On the other hand, the Stedelijk Lyceum is reported to have a safe and positive school climate, which could stimulate a higher degree of learning within the students. Students will probably also be familiar with the christian themes within Renaissance literature, since a large portion of the population in Twente identifies as christian (although the majority does not regularly visit church ceremonies). In conclusion, because of the low intrinsic motivation and adolesents having weaker metacognitive abilities, the tool should facilitate the planning process so that the students only have to focus on the learning itself.

[3] `https://github.com/mcvdenk/MasterThesis-Software/blob/master/database/flashcards.json`
[4] `https://github.com/mcvdenk/MasterThesis-Software/blob/master/database/itembank.json`

Defining the general use cases

Supplantive or generative

The first important design choice which has to be made is whether the students are supplied with a concept map or flashcards, or that they generate the content themselves. The dichotomy of generative versus supplantive instruction is described in further detail by Smith and Ragan (2005), where the implications of both sides are enlisted for the learner, the task and the context.

One of the aspects of generative strategies is that the learner requires a higher amount of prior knowledge, a higher aptitude, and a wider and more flexible range of cognitive strategies, because the content still has to be (partly) researched and constructed. This can be a disadvantage, because the learner might not possess these skills and therefore the instruction may not be suitable or highly inefficient using generative strategies. On the other hand, greater mental effort generally leads to greater depth of processing and therefore better, more meaningful learning, which was also stressed by Cañas and Novak (2012) and Nesbit and Adesope (2006). Furthermore, learners experience a higher motivation and a lower amount of anxiety when using generative strategies, and their attribution of success is internal rather than external.

Furthermore, when using more generative strategies, the learning task becomes more complex and ill-structured, and therefore requires more instruction and time to complete. It also leads to a higher focus on cognitive strategies, but less so on the learning goals. These goals can also not become universal, since each student creates their own flashcards or concept map, and therefore decides on their own learning content.

The most important factor for this design choice is feasibility. The teacher already stated that there is only limited time available during the lesson to introduce them to the software, so there is no time for extensive instruction on how to create concept maps, let alone creating the maps within the classroom. Additionally, students do not have much time at home to spend on creating the maps, and it is also known from both interviews with the teacher as literature that they will probably have only a low amount of intrinsic motivation. Finally, when the students have to create their own maps, it cannot be guaranted that they will include the nodes relevant for the goals of the instruction, and might become either to narrow or to extensive in certain branches. The same arguments are valid for letting students create their own flashcards. Therefore, despite of the benefits that a more generative approach may have for the learning process, the content will be supplied to the students instead.

Choice of platform

The next design decision is centered around the choice of platform or medium going to be used in order to support the learning tool. In the section Application of flashcards on page 11 it is described that students generally prefer to use traditional or written flashcards, despite the many advantages of digital flashcards. However, with the flashmap tool this is not a feasible option, since the tool has to dynamically generate different graphs based on the general concept map and the profile of the students. Of course it would be possible to provide the concept map digitally and the flashcards in written form, however this would introduce an extra variable to the research design. Finally, with written flashcards one can only use rather crude methods for rescheduling the cards, instead of using the more precise algorithms possible within a digital tool.

There are various options for the specific implementation, for example a computer program or an app. Of these options, a web application is the most convenient, since it is accessible for any device with a modern web browser, and immediately stores the usage data on a centralised server so that it is immediately accessible for the researcher. Furthermore, adjustments or fixes can be applied during the research, without all users having to update to the newest version.

For the client, HTML, CSS, and Javascript are used, importing the vis.js library for visualising the concept map dynamically[5]. Furthermore, Python is used for the server logic, communicating with the webclient through a websocket using JSON messages. The choice for Python is mainly based on preference by the programmer. Finally, MongoDB was used as a database engine since it stores data in a format very similar to JSON, which is also used by vis.js to represent concept maps.

The server implementation will be further elaborated in the Server design and development chapter on page 55, and the client implementation in the Client design and development chapter on page 65.

Supported user actions

The final design decision related to the general ideation of software is deciding which use cases should be supported, which are generally displayed within a UML use case diagram ((OMG), 2015). For the flashmap software, the use cases are divided in cases related to the registering and login process (see figure 15), and the cases related to the main use of the software (see figure 16).

Login use cases When opening the webapplication, the user is first prompted with a login screen. Here, th e user can either enter an already existing username to continue this session, or he can enter a new name in order to register as a new user. When the user is registering as a new user, a form is presented asking for information on gender and birthdate as descriptive information, and asking for the specific code the user received on the informed consent form in order to validate that the user indeed signed this form before partaking in the research (see section Procedure on page 72). After that, another form will be prompted for the pretest (section Instrumentation on page 72). When the user has met certain criteria, a posttest similar to the pretest will be prompted, followed by a questionnaire and a debriefing text. When none of these criteria are met, the user can access he main use cases.

Learning use cases The main use cases entail requesting items for review, requesting the learning progress, or logging out. When requesting items for review, the user can receive a due or new flashcard or flashmap, depending whether there are any old items due for review and the experimental group the user is in. Alternatively, the user can also be prompted whether a certain section of the instruction material has been read, since the rehearsal of items cannot be meaningful when the user is not familiar with the content. These prompts take often place at the beginning of a session so that the user does not have to interrupt a session. Furthermore, they prompt two sections ahead of the material currently being learned or reviewed by the user from the flashmap

[5] `http://www.visjs.org/`

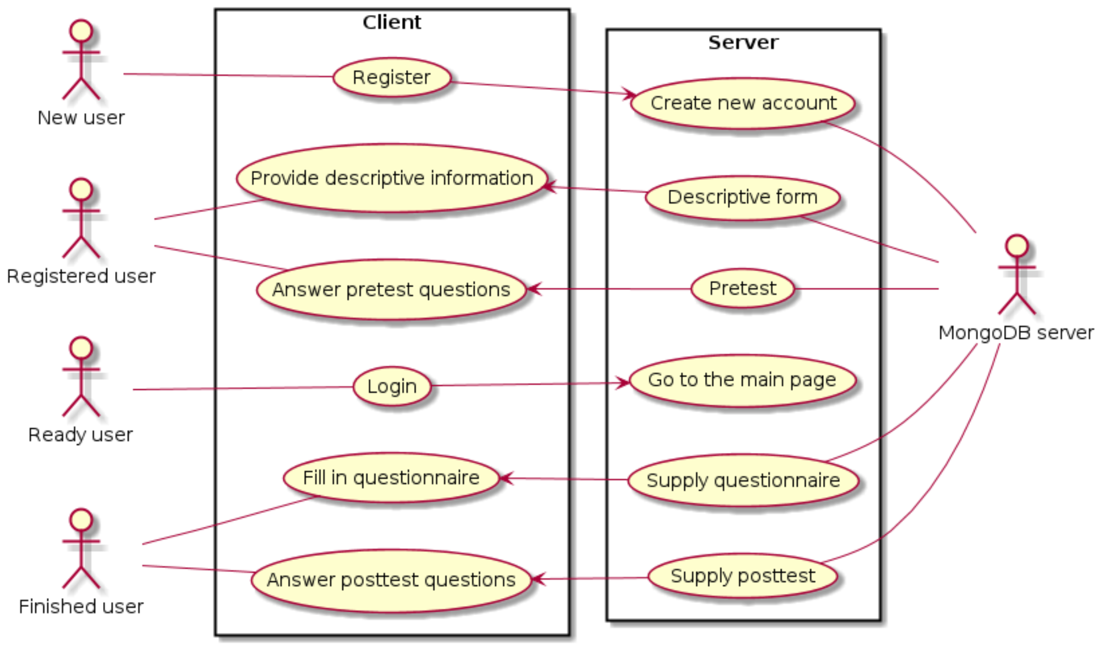


Figure 15: An UML use case diagram for registering as new users or logging in as existing users

or flashcards in order to guarantee that the user is familiar with the material before learning the items. The user is prompted to read a section at most once per day. After the user has submitted a response, he can undo this response if he is not content with it. For example, the user could after seeing the correct response decide that he thought of a similar enough answer, but after deeper reflection still decide that his answer was not sufficient. In this case, he could use the undo option in order to be presented with the previous response again and select the 'incorrect' option.

Learning progress When requesting the learning progress, the user is presented of an overview of what has already been learned and what is still left as either unseen items or items due for review. This provides an indication for the user so that he can estimate how much time he still needs to invest into the software, but also could stimulate the user by seeing the number of new or due items lowering and learned items increasing.

Finally, the user can return to the login screen by logging out.

Detailed description of the client server interaction

Based on the previous description of use cases, there are two sets of complex interaction between the client and server, which are again the interaction for the login and registering process, and the interaction for the learning process. These are described as UML activity diagrams ((OMG), 2015) in figure 17 and figure 18. These diagrams are elaborated on below together with the specific network messages belonging to the interaction step. Each network message is a simple JSON message consisting of a *keyword* field — containing the main function which has to be performed by the other party — and a *data* field containing a dictionary with necessary supplementary data.

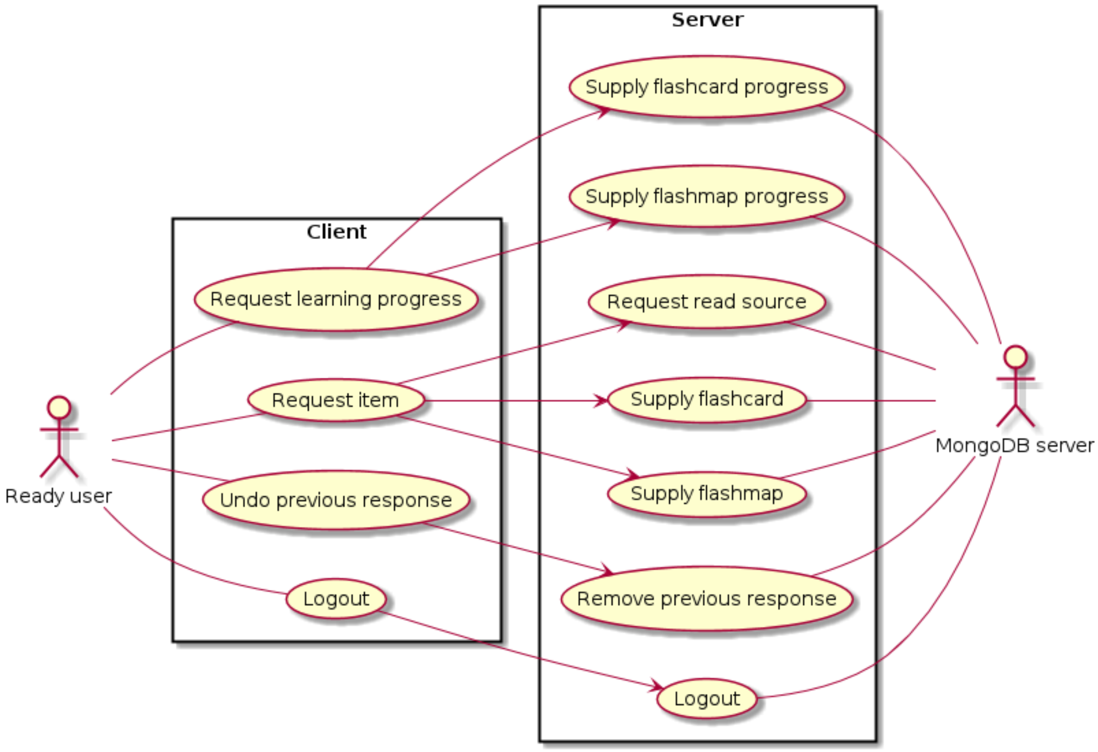


Figure 16: An UML use case diagram for main uses of the application

Login activities

The exact reasoning behind the different activities can be found in the Procedure and Instrumentation sections of the Methods chapter on pages 72 and 72.

Authenticate When the user logs in, the client sends a message with keyword "AUTHENTICATE-REQUEST" and data containing a name field with the username. When a user with this username does not exist yet, the server creates a new user with a randomly assigned condition (either flashcard or flashmap, also known as control or experimental). When this user already exists, the server fetches this user from the database.

Descriptives The server then checks whether the user already has set description fields. If not, the server returns a message with keyword "DESCRIPTIVES-REQUEST", on which the client responds with keyword "DESCRIPTIVES-RESPONSE" with the data fields gender, birthdate, and code.

Pretest When the previous condition is met, the server will check whether the user has a registered pretest. If this is not the case, it will create a new test by randomly selecting 5 items from the flashcard dataset and 5 items from the itembank, which it will then send to the user with the keyword "TEST-REQUEST". After the user has answered the questions, the client sends the responses to the server with the keyword "TEST-RESPONSE".

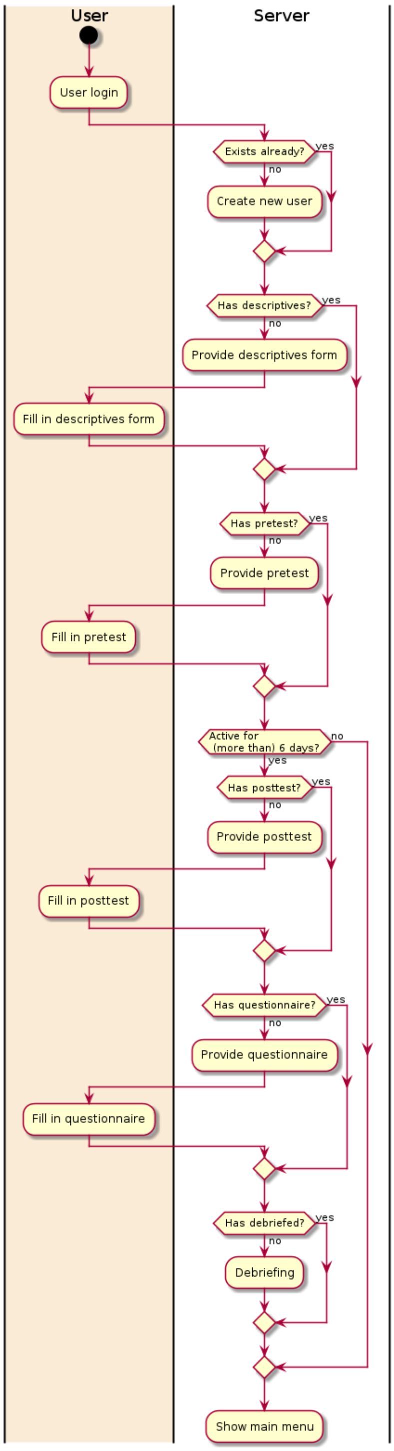


Figure 17: An UML activity diagram displaying the server-client interactions when a user logs in

After the experiment If the previous condition is also met, the user will be directed towards the main application with an "AUTHENTICATE-RESPONSE" message from the server, unless he has used the software for at least 15 minutes on 6 days. In that case the checks described below will be performed.

Posttest In this step the server checks whether the user also has a posttest entry. When this is not the case, it will send a similar test message to the pretest message, with the exception that the flashcards and test items from the pretest are excluded from the random selection in the posttest.

Questionnaire Sequentially, if the user has no questionnaire entry, the server will construct a new questionnaire by shuffling the Perceived Usefulness item, randomly selecting for each item whether it is positively phrased or negatively, copying this item set but with the opposite phrasing, and finally shuffeling the second set. The same is done for the Perceived Ease of Use items. This questionnaire is then sent to the client with the "QUESTIONNAIRE-REQUEST" keyword. The client sends a filled in version back with the "QUESTIONNAIRE-RESPONSE" keyword to the server with an extra textfield for what was good about the software, what could improved about the software, and an (optional) emailadress of the user for an interview at a later time.

Debriefing Finally, if the user has not debriefed before, the server sends a message with the keyword "DEBRIEFING-REQUEST" to the client, which will show a debriefing message to the user and returning a message with the keyword "DEBRIEFING-RESPONSE". When all the checks are met, the user will be directed to the main application with the "AUTHENTICATE-RESPONSE" message.

Learning activities

In the main application view, the user can either review items or view his learning progress. If he chooses the latter, a message will be sent to the server with the "LEARNED_ITEMS-REQUEST" keyword, to which the server will respond with a "LEARNED_ITEMS-RESPONSE" message containing information on the learning progress (see the Learning progress section on page 68). If the user wants to review items, the client will send a "LEARN-REQUEST" message to the server and the process described below is performed.

Aimed time reached First, the server checks whether the user already spent 15 minutes learning today. If this is the case, the client will display a message that the user has spent an sufficient amount of time on learning for today. This will not be directly be displayed as the activity diagram suggests, but rather it will show this message together with the next item.

Selecting an item After this, the server will check whether there is any item already due for review. If this is the case, the server will sent the item which is due for the longest time to the client with the keyword "LEARN-RESPONSE". If not, the server selects a new item from the database. It is then checked whether the user already read the section in the book related to this item. If not, the server sends a "READ_SOURCE-REQUEST" to the client, which prompts the user whether he has read the source supplied in the source field of the message. If so, the client sends a "READ_SOURCE-RESPONSE" message back to the server, which adds the supplied source to the list of read sources for the user. When the user has read the section , the server will sent a "LEARN-RESPONSE" message with a new item from the database. If there is no new item left, the server sends a message to the client with the keyword "NO_MORE_INSTANCES".

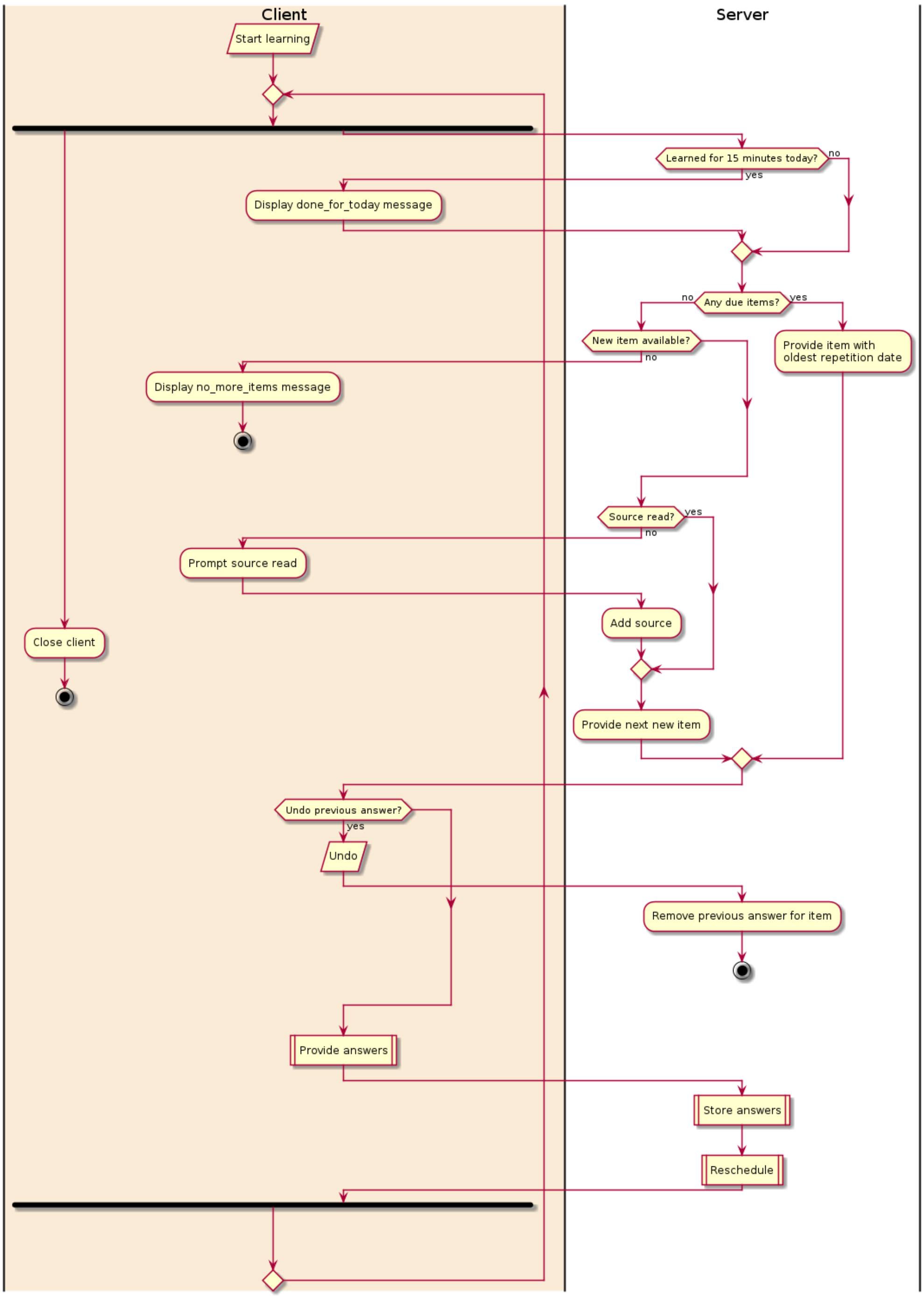


Figure 18: An UML activity diagram describing the general server-client interactions related to reviewing items. The *Provide answers* activity is described in more detail on page 66, and the *Store answers* and *Reschedule* activities in figure 23 on page 63

Validating the item When the user has reviewed the item, the client sents a "VALIDATE" message to the server with an 'id' field with the item id and a 'correct' field with information whether the user was able to think of the correct response for the item. This response will then be stored in the database by the server, and the item will be rescheduled for when it is due for the next review. After this, the server will repeat the learning cycle as if the client just sent a "LEARN-REQUEST" message.

Undo previous response When the supplied item is not the first item within the current learning section, the user can choose to undo the response of the previous item. The client will then send back a "UNDO" message to the server, which will then remove the previous response and also go back to the beginning of the learning cycle.

Design frameworks

This chapter describes the general design frameworks used for the implementation of the use cases defined in the previous chapter. These frameworks are Concept map construction design features (Novak & Cañas, 2008), flashcard learning design features (Nakata, 2011), and the two factor theory for website design (Zhang & von Dran, 2000). The aim is to implement these features from the next sections within the flashmap software in order to enhance the quality of the tool. Within the Server design and development and Client design and development chapters it is described when the sofware does not adhere to one of these original design features.

Concept map construction design features

Unfortunately, little is written about the design of clear concept maps for supplantive use. Only one technical report by (Novak & Cañas, 2008) is written on how students should construct concept maps, however the main focus of this document is on how this process can be scaffolded rather than discussing good design features of concept maps. The only two features mentioned are:

- Cross-links are important in order to show relationships between subdomains in the map (also mentioned by Eppler (2006))
- One should avoid "String maps", which are maps mainly consisting of large sentences within the nodes

The developed concept map therefore focuses on meaningful relations between concepts rather than hierarchical structure, and divides nodes into smaller nodes whenever one node becomes to large.

Finally, Eppler (2006) describes that concept maps are top-down diagrams rather than radial diagrams, therefore the graph layout will be hierarchical with top-down orientation.

Flashcard learning design features

Nakata (2011) describes a framework for developing flashcard applications based on several design features generally present in all major flashcard systems, and findings of earlier studies. The framework is split up in features aimed at creation and editing of flashcards, and at learning of flashcards. However, the creation and editing features are not relevant to the design of the flashmap system, since the content is already developed for the students. Furthermore, the Flashcard systems reviewed by Nakata (2011) are aimed at vocabulary learning, so not all of the guidelines mentioned in the review can be fully generalised to the flashmap system. That being said, there is still quite some overlap between the functionality of these reviewed systems and the flashmap system, and even if a principle is not (completely) applicable it is still relevant to know why this is not the case and what should be the guideline instead.

The flashcard learning features can be split up in two subcategories, which are features related to how the cards are presented (Presentation and retrieval modes, Retrieval practices, Increasing retrieval effort, and Generative use), and features related to the rescheduling of cards for review (Block size, Adaptive sequencing, and Expanded rehearsal). All features are expounded in the following subsections.

Presentation and retrieval modes

It is recommended to use two different modes, namely the presentation mode — where users can familiarise themselves with not seen before flashcards —, and the retrieval mode — where the user tries to actively retrieve a target when shown the associated cue. The presentation mode is introduced, because retrieval of unfamiliar targets would only result in unsuccessful performance and negative effects on the motivation of the user. Nonetheless, it was decided to only include the retrieval mode, since the students have already familiarised themselves by listening to the teacher explanation and reading the book, which can already be regarded as a presentation mode.

Retrieval practices

Retrieval practices relate to the ways the system prompts the user to recall a target from memory. Within vocabulary learning, there are four different categories of retrieval practices divided into 2 axes: reception versus production, and recall versus recognition.

Reception and production

The first axis of reception and production relates to which part of the associated pair should be retrieved. Reception means that the meaning of the word should be retrieved, whereas production refers to retrieving the target word. For example, when having the pair "Goedenmiddag" and "Good afternoon" while learnig Dutch vocabulary, with reception "Good afternoon" would have to be retrieve when being shown "Goedenmiddag", whereas in productive recall "Goedenmiddag" would have to be retrieved when being shown "Good afternoon".

Recall and recognition

The second axis refers to how the retrieval takes place, namely whether the student tries to recall the cue from memory (recall), or whether he chooses the correct answer from a list of possibilities (recognition). For example, when presented with "Goedenmiddag", when using recall the student should think of the correct answer on his own, where when using recognition the student should choose the correct answer from a list, e.g. "Good morning", "Good afternoon", or "Good evening".

According to Nakata (2011), it is difficult for students to aquire both the word form-meaning connection and the word form of a word simultaneously, mainly because of limited cognitive resources. Therefore, good vocabulary learning software should split these tasks into separate exercises: one using reception or recognition (or both), and one using specifically productive recall.

In the case of using flashcards for learning texts, reception and production could be interpreted as prompting the question versus prompting the answer. Recall and recognition still work in the same way, namely as an open prompt or a multiple-choice prompt. In flashmaps however there are not 2 elements but 3 elements per prompt — the parent node, the edge, and the child node — and this makes way for 6 options rather than 2 options for the reception-production axis, which are displayed in table 3. Within the table they are ordered from leaning towards reception to

	Parent node	Edge	Child node
1	X	X	
2	X		X
3		X	X
4	X		
5		X	
6			X

Table 3: The different possibilies for the reception-production axis in the flashmap system, with an hypothesised ordering from more leaning towards reception to more towards production. The shown elements for each retrieval mode are indicated by an X, whereas the other elements would be the targets for retrieval.

learning towards production, with the underlying hypothesis that retrieving the child node is more in allignment with reception whereas retrieving the parent node is more in allignment with production. This of course also depends on the concept map. The recall and recognition axis still stays the same, where in the latter case the possible options could be displayed next to the flashmap.

Only one retrieval practice was chosen for this experiment in order to keep the amount of variables to a minimum and thereby make a better comparison between the conditions. For the flashcard condition, the receptive recall was chosen, since this was the skill most relevant to the test itself. The flashmap equivalent was retrieval practice 1 from table 3 combined with recall (in contrast to recognition). Other retrieval practices are however still worth investigating in further research.

Another consideration here not mentioned by Nakata (2011) how the answer retrieved by the student should be compared with the actual answer. In the case of recognition, the user could simply click on the answer he thinks to be the correct answer, which can then be compared to the correct answer. Within the case of recall however, the student either has to merely indicate whether his response was in allignment with the correct response, or he has to type his answer which is then compared to the correct response by the software. The latter option was chosen, since this is easier for students using a mobile plattform to only press a button in comparison to typing on the screen keyboard. Furthermore, typing out an answer can lead to unintended rigidity of the system, such as an answer being marked as incorrect with spelling errors or omitted articles, or a highly increased complexity when trying to take into account these alternative correct responses. The only downside to this decision is that within the results there is an increased unreliability in how leniant the students were with their response being correct or incorrect.

Increasing retrieval effort

The design feature of increasing retrieval effort is strongly related to the choices made with regards to the previous design features. It entails that over the course of multiple presentations of one associated pair, the challenge of retrieval should be increasing. Nakata (2011) describes that this can be achieved by starting with the presentation mode before introducing the retrieval mode, and by gradually shifting from recognition modes to recall modes and from receptive modes to production modes. However, since the presentation mode is omitted and only one retrieval practice is chosen within this project, increasing retrieval effort is not feasible in this way. This again could be incorporated in later prototypes where other retrieval practices are incorporated.

Generative use

Generative use of words refers to presenting words in novel contexts. In the case of vocabulary learning, one can use specific words in different sentences which underly the different meanings of the words. Generative use also enhances the elaborative processing of certain concepts. Within the flashmap system, this is incorporated by presenting the concepts together with different edges, sometimes because a concept switches from child node to parent node, but in other cases because multiple unique edges direct from or to a concept. Within the flashcard system, this is also the case but more implicit, because every edge (or group of similar edges) being translated to flaschards, and thereby incorporating the concepts in multiple questions and answers. The only concepts appearing in one instance would be the concepts with only one outgoing edge (root node, K=1), since they only appear in one question, or only one incoming edge (leaf node, K=1), since they only appear in one answer. Of these, the root node promblems can be eliminated by creating more direct subconcepts in the hierarchy or omitting the direct subconcept and linking its subconcept direct to the root node. The leaf node problems are more difficult to eliminate, but still can be linked to other concepts by creating more cross-links generating more incoming or outgoing edges on the lower levels. However, this is not always possible, since some leaf nodes cannot be meaningfully connected to other nodes. In this case it is also worth considering whether this node could be eliminated altogether.

Block size

Within the Spacing effect section on page 20 it is described how repetition of an item is more effective when interleaved by other items (spaced items) than when repeated in immediate succession (massed items). The block size is therein defined as the length of items after which items are repeated again. When using massed items, one would have a block size of one, whereas when interleaving each repetition by 8 other items, the block size would be 9. The Implications for the flashcard system section however describes why it is better to use adaptive spaced-repetion learning instead of fixed block sizes, which is also recommended by Nakata (2011). Therefore, no specific fixed block size will be used within the scheduling algorithm.

Expanded rehearsal

According to Nakata (2011), expanded rehearsal is widely believed to be the most effective. The main difficulty for choosing the right slope for the expanded rehearsal is to balance between overlearning — repeating items too often, reducing the effectiveness of each repetition — and the forgetting curve — repeating items too little, leading to the students forgetting the card and thereby frustrating the user and even ineffective studying.

The first system which implemented this system is the Pimsleur system, where over the course of a 30-minute audio lessons words would be presented in a progressive series of exponentially expanding intervals with a base value of 5 seconds (Edge et al., 2012). This means that the first repetition would take place after $5^1 = 5$ s, the second after $5^2 = 25$, the third after $5^3 = 125$ s, etc. This system thereby already took into account the decreasing slope of the forgetting curve because of the power law of learning (see figure 8 on page 8), preserving a steady retrieval chance with a decreasing amount of repetitions. This curve is possibly too flat and leads to increased overlearning, however overlearning can also lead to a benefitial confidence within the user because of the higher percentage in correct retrievals. The Pimsleur system is also rather simple, reducing the amount of variables in the research. Because of these reasons, it is chosen as the basis for the flashmap scheduling algorithm.

Adaptive sequencing

An adaptive sequencing algorithm takes into account the learners' previous performance on individual items when rescheduling an item for the next review. Within the original Pimsleur system, one would always increase the time interval for the next review independent of whether the student could correctly recall the item or not. However, this does not account for the flashcards which are more difficult or forgotten at the time of the new review, resulting in the user not being able to keep up with those cards.

The first system to implement an adaptive sequencing element is the Leitner system, which is also the most basic adaptive sequencing system. The user has a number of piles, each representative of a expanded time interval, and a stack of physical flashcards. Each time a flashcard is answered correctly, it moves to the next pile, resulting in a larger time interval before the next repetition, and when answered incorrectly it would be moved back to the first pile. The rationale behind this system is that when an item cannot be retrieved it is forgotten, and the expanded rehearsal should therefore be reset to the lowest value.

The main problem with the Leitner system is that when it was introduced, managing the flashcards and different piles was quite a hassle. This problem was resolved with the introduction of digital flashcards, since the computer could take care of the scheduling and bookkeeping of the flashcards and their reviews. The Leitner system is therefore still prevalent in most digital flashcard systems (e.g. superMemo, Anki, and FaCT).

When combining the Pimsleur and Leitner system as one system, one gets the formula $i = 5^c$ for scheduling the flashcards, where i is the time interval in seconds, and c the amount of times the flashcard was correctly retrieved for this item since the last incorrect retrieval (or the total amount of retrievals when there were no incorrect retrieval).

Edge et al. (2012) introduced an even more sophisticated system, namely the adaptive spaced repetition system. On top of the Pimsleur intervals and Leitner adaptive sequencing, it also adapts the time intervals based on the amount of answers correctly and incorrectly answered by the student for each time interval. This results in specific time intervals better catered towards the user's ability. This is not included within the scheduling algorithm used within this project, because it adds another variable to the experiment. It can still be included however when aiming to improve the prototype.

The ARCS model

In the Analysis of the learner section, it was already found that it is likely for the students to have a low intrinsic motivation for engaging into the subject matter. Therefore, it is also important to include a framework within the motivational domain next to the previous framework focusing mainly on the cognitive domain. A commonly used and well researched model for incorporating motivational features is the ARCS model (Keller, 2000), which is an acronym for Attention, Relevance, Confidence, and Satisfaction. The factors were applied within the application where possible, however many are also applied within the context outside of the application. They all can be expressed in three subcategories, described in the following sections.

Attention

In this instance, the category of attention mainly refers to gaining attention at the beginning of an instruction, whereas keeping the attention is covered by the other categories. It can be gained by simple unexpected events, or mentally stimulating problems engaging the learner. Furthermore, variety is important for the effect not wearing down.

Perceptual arousal This mainly refers to the simple events — such as whistles or strange imagery — in order to capture the interest from the learner. In order to achieve this for drawing the user towards using the system, the researcher went to the classroom in the last lesson where the subject material was taught, where the attention was mainly gained from the effect of having someone else than the teacher appearing in the classroom. Within the system itself it was harder to achieve, since the content of the instruction was dynamically generated and therefore it is more difficult to find fitting content for each study session. It would then also add extraneous cognitive load, which is undesirable both for the learning achievement as well as the experimental setting.

Inquiry arousal This relates to the deeper, mentally stimulating problems which can be offered to the student in order to activate engagement with the topic. Related to the content itself, this is mainly done by the teacher within the lessons and by the instructional material. The researcher also tried to stimulate inquiry by stating that this was an early opportunity for the students to experience what research on a university looks like. Finally, by continuously asking questions users are also stimulated to actively participate in the instruction.

Variability Finally, if the setup for every instruction is the same, learners will eventually get disengaged because of the predictability. Using this system instead of the usual chapter reading in preparation of an exam might be an example of breaking such a predictable pattern. On the other hand, one of the downsides of drill and practice is its repetitive nature, so this could demotivate or disengage the students.

Relevance

Gaining arousal is not enought to keep the learner engaged over a long period of time. One method therefore to keep the attention is for the user to understand why it is relevant to engage in the learning activity. The subject matter however is not that interesting towards the average high school student. Therefore, the presentation of the system by the researcher will mainly focus on how it can help students to effectively and efficiently prepare them for the exam, since this is likely to be their direct goal.

Goal orientation The first step in establishing relevance is to relate to the needs and goals of the learner. In order to achieve this, the introduction by the researcher mainly delves into how a general flashcard system works and how it benefits learning, making the process more effective and efficient than purely reading through the book. Added to this, it is mentioned that some of the flashcard and test questions will be repeated on the actual test used for grading the students, making it extra attractive because of the sneak preview.

Motive matching This relates more to provide learners with appropriate choices, responsibilities, and influences. One way to do this is by modeling, derived from the theory of planned behaviour (Ajzen, 1991). In order to convince the students that the software is reliable, the researcher adds an anecdote from his own experience of using the system, and that by using it he had a guarantee of being well prepared for exams because of how the algorithm works.

Familiarity This subcategory mainly refers to tying the content to the learners' experiences. Unfortunately, the content of the instruction does not lend itself well for this subcategory, hence it is also not used in the instructional material and thereby in the flashmap and flashcards. However, the teachers made great effort within the lessons itself to explain how the renaissance genres and techniques are still prevalent in todays writing, with examples known to the learner.

Confidence

The learner must, next to feeling the subject matter is relevant, also be confident that he is able to learn the subject and to perform the learning activities successfully. This confindence can be boosted by creating the right expectations and providing positive feedback related to the learning activity.

Learning requirements One way the confidence can be boosted on beforehand is by assisting in building a positive expectation for success within the learner. In this case this is done by the researcher first acknowledging that learning and comprehending the core message of a text can be difficult, but that the system can assist this process greatly and makes it easy to do. This is also done within the initial presentation of the software. Furthermore, within the presentation as well as within the software it is made clear that the researcher could support individual learners at any moment if they would get stuck using the application. Within the software this was achieved by including a separate help page with explanations on how to use the software, by including a small text above the main content explaining what the user should do within the current step, and an email address in the navigation menu for contacting the researcher himself.

Learning activities Additionally, the learning activities themselves can also support or even enhance the students' beliefs in their competence. Within the flashcard system this is done by having the relatively flat expanded rehearsal slope from the Pimsleur system, which generates more overlearning and thereby increases the amount of correct retrievals. A more steep slope would result in more failed retrieval attempts, increasing the frustration within the user and thereby requiring a more stoic attitude.

Success attributions Finally, the learner also has to attribute his success to the use of the system in order to be motivated to use it. However, according to Logan et al. (2012), judgement of learning of students using spaced items does not appear to be higher than when using massed items. Therefore, a separate overview is included within the system displaying the progress the learner has made and how much items are still left.

Satisfaction

Finally, in order to sustain motivation after the student is attentive towards, understands the relevance of, and is confident about performing the learning activities, satisfaction is required. This is mainly related to positive feelings stemming from the reward system, and are generally categorised in intrinsic and extrinsic motivation.

Self-reinforcement Intrinsic satisfaction is probably the most powerfull satisfaction, since it works directly on the short-term. This feeling can be instigated for example when the learner is intrigued by the subject, but also when he experiences some form of achievement. It is already stated within the Analysis of the learner that most students will most likely not be highly interested within the subject matter, and therefore the first category of intrinsic satisfaction will only be met in rare cases. However, successful retrieval does lead to a sense of achievement, next to it being a confidence boost and effective learning tool. Therefore, the flashcard system itself might already facilitate self-reinforcement.

Extrinsic rewards An important extrinsic motivator for the student is to pass the test at the end of the course, for which this system is an effective aid. However, as the teacher already stated before the experiment, this motivator is probably not enough motivation for the students to spend extra free time in such a tool. This is mainly because students often overestimate their own abilities and thereby deeming the extra preparation as not necessary, and them being less able to oversee long-term consequences because of their prefrontal cortex still being in development. In order to create an extra reward, the students are rewarded with a coupon for icecream if they successfully committed to he whole experiment. This entailed filling in the pre- and posttest and questionnaire, and spending 15 minutes every day over the course of 6 days on the system. This reward of icecream seemed to be what the students were most excited about during the initial presentation by the researcher.

Equity Finally, it is imporant that each learner has a feeling of fair treatment. This entails that there was an appropriate amount of work, that the work they did is related to the final test, and that there is no favouritism among students. Using the system might feel as extra work to the students in comparison to just reading the textbook, even if it attributes to a higher chance of passing the test. This is an extra reason to emphasise the added value of using the software during the presentation. Furthermore, the consistency of the learning content and objectives and the test is guaranteed by deriving the concept map directly from the instructional material, by including flashcards and pre- or posttest question on the school test, and by letting the teacher confirm that the flashcards cover what the students have to know for the test and that there are no extraneous flashcards. Finally, equity is guaranteed by the fact that all students have anonymous accounts and thereby exactly the same general treatment during the learning procedure. The only contingency is that some students are using the flashcard system while others using the flashmap system, which might provide one group with advantages over the other group.

Server design and development

In this chapter, the general model behind the server will be elaborated. The formal documentation with descriptions of the server classes and their methods can be found on page 87, which also includes an UML class diagram ((OMG), 2015). An HTML version of the documentation is also available on `mvdenk.com/thesis/doc/`, and the entire source code is available at `https://github.com/mcvdenk/MasterThesis-Software/tree/master/server/`. The description of the model is divided in generic data entries — entailing the supplanted data by the developer such as the concept map or test items — and the user attributes, objects and methods — entailing user specific data such as birthdate or how often a user responded correctly or incorrectly to a certain instance. Only the conceptually relevant methods will be described below, since this keeps the thesis more accessible for readers not familiar with programming paradigms, and these methods are already described within the documentation. For example, the to_dict() method is prevalent in a large amount of classes, but merely serves the purpose of converting the class into an object that can be sent over the network connection to and rendered within the client and therefore is not conceptually relevant and is not elaborated. The two classes left out of the description are the Controller class, which parses client messages, operates the server and translates the server output to a new network message, and the LogEntry, which represents a single incoming or outgoing network message. These classes are also not conceptually relevant, and their functionality can already be derived from the previously described UML Activity Diagrams in figure 17 on page 43 and figure 18 on page 45.

Generic data entries

There are four classes of generic data: the concept map (containing nodes and edges), the flashcards, the test items and the questionnaire items. The concept map and flashcard model is illustrated in figure 19.

Concept map

The ConceptMap class is mainly a container class consisting of nodes and edges, and certain useful methods for performing standard queries on the concept map. As described in the general definition of the concept map by Cañas and Novak (2012), a Node object represents a concept, and an Edge object represents a relation between two concepts. The Node and Edge were originally intended to be embedded within the ConceptMap class, however this makes them impossible to refer to by other classes in MongoEngine (used for interacting with the MongoDB database). Furthermore, it could theoretically be possible for certain Nodes to exist in different concept maps. Therefore, they are implemented as separate classes in this server model. The example concept map in figure 20a is used to demonstrate the different functions in of the class.

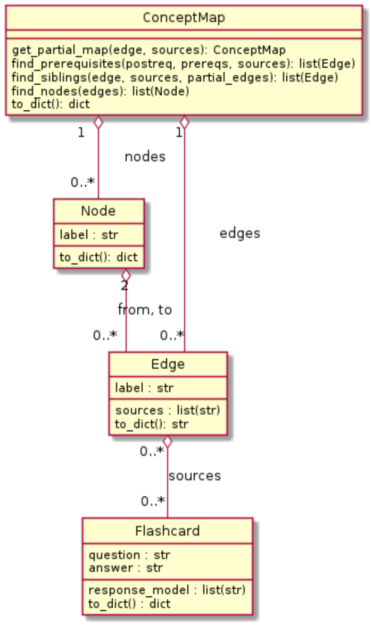


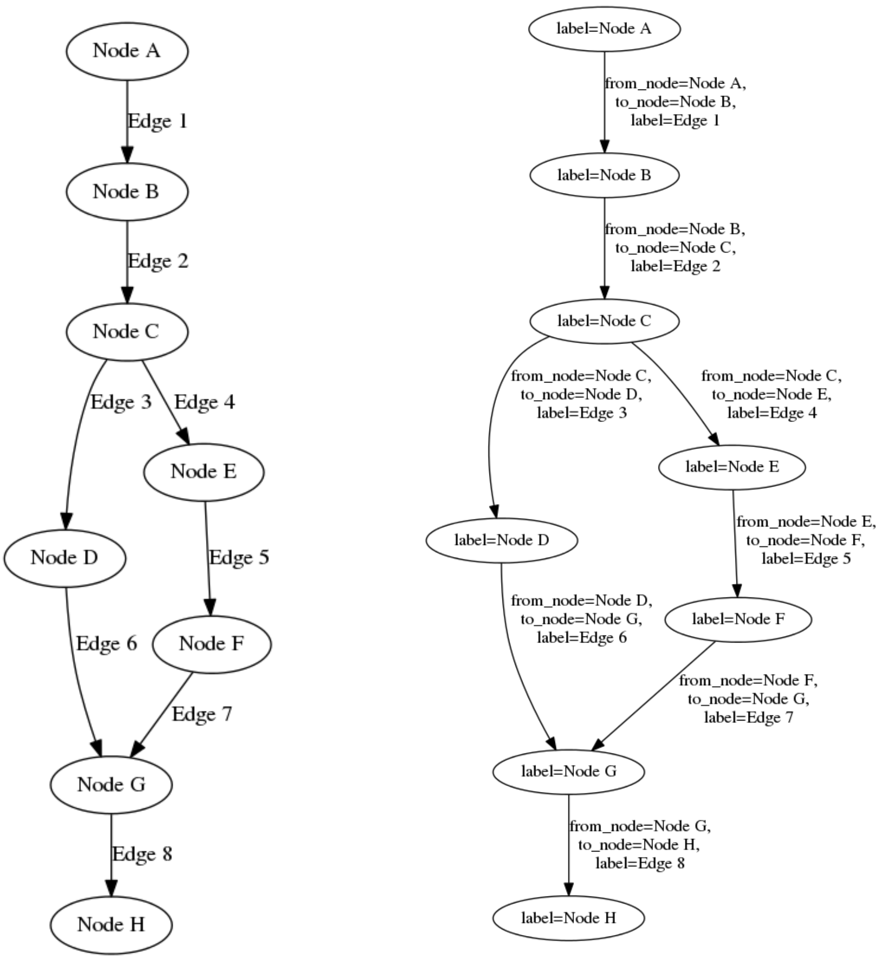
Figure 19: A UML class diagram illustrating the ConceptMap, Node, Edge, and Flashcard classes

Nodes The concepts represented by the nodes are not only an abstract ideas (such as Renaissance Literature), but also more concrete concepts such as a time period (e.g. the Golden Age), a person (e.g. P.C. Hooft) or objects or inventions (e.g. the printing press). Nodes are simple classes only containing a label describing what it should represent and a unique identifyer string.

Edges An Edge also contains a label describing the specific relation between two concepts and an id, but also contains the references to the id's of the nodes it refers to, one being the 'from' node and the other the 'to' node, and a list of sources (usually only containing one source), which are the sections of the instructional material the edge is derived from. The model does not make any destinction between a hierarchical and cross-link, since they are the same from a graph rendering perspective. However, this destinction might still be considered for more sophisticated hierarchical rendering or searching algorithms. The Edge class is chosen as the equivalent to the Flashcard in the Flashmap system rather than the Node, since a relation between concepts is more specific when teaching about concepts. Furthermore, within an Edge object there is already a clear question (the from_node) and answer (the to_node).

Figure 20b demonstrates how the different classes and attributes represent the concept map from figure 20a.

Methods The most important method of the ConceptMap class is the get_partial_map() function, which will provide a new ConceptMap object containing all the parent nodes and edges which directly or indirectly link to a given Node (the parent nodes and edges), plus the nodes and edges linked to by the direct parent nodes (the sibling nodes and edges). This concept map can then be displayed to the user when showing a specific flashmap instance for review. The reason why the parent nodes are returned rather than the child nodes is that in the instructional material the concepts are introduced top-down rather than bottom up, so building up the concept map from parent to child alligns better with the order in which the students read about the concepts.



(a) An abstract example of a concept map

(b) The different attributes demonstrated within the example map from figure 20a

Figure 20: An example illustrating the ConceptMap class

Additionally, the sibling nodes are also returned so that they can be prompted at the same time, and that the user has more context for deciding which concept should be filled in the missing node. Figure 21a and figure 21b demonstrate the get_partial_map() function with Node D and Node G from the example map in figure 20a.

Flashcards

A Flashcard class represents a traditional flashcard by simply having a question and answer entry. It addtitionally has an response model entry in order to also function as a test item. In most cases, this is a list only containing the answer entry, however in some cases the answer entry is split into multiple response entries. Finally, since each flashmap is based on the concept map, each Flashcard object also contains a list with Edges the card is derived from. This has the advantage of being able to compare the flashcards with the concept map, but also indirectly relates the flashcards to the sections within the instructional material.

Test items

A TestItem object represents an item on the pre- or posttest. It is very similar to a Flashcard object, with the exception that it directly links to the text sources, and does not contain an answer field since this is never displayed to the user.

Questionnaire items

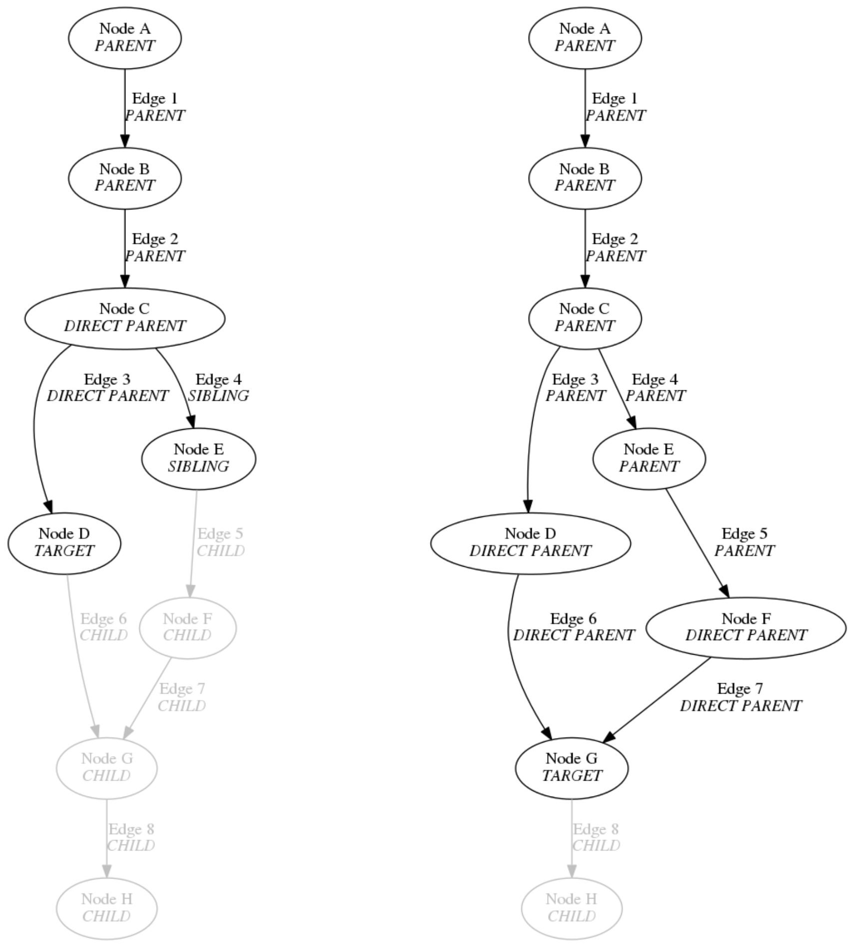
The QuestionnaireItem class represents items from the Technology Acceptance Model questionnaire (Davis, 1989), and contains a usefulness entry categorising the item as either a Perceived Usefulness item or as a Perceived Ease of Use item, and a positive and a negative phrasing entry. Both phrasings are included instead of only the standard positive phrasing, so that one of these phrasings can be selected when presenting the item to the user, avoiding only one type of phrasing causing a bias within the user towards that specific phrasing.

User attributes, objects and methods

The main user attributes are mainly based on the aforementioned generic data entries, namely the FlashcardInstance or FlashmapInstance objects — storing the learning progression of certain Flashcards or Edges from the ConceptMap —, the Test objects — representing a pre- or posttest and containing the responses to sets of TestItems —, and the Questionnaire object — containing the responses to the QuestionnaireItems. Next to these objects, the user also has certain descriptive attributes, and objects related to logged in sessions. The User class and its attributes and embedded classes are illustrated in figure 22.

Descriptive attributes

The descriptive attributes are either used for the program to function, or for generating descriptive statistics as controll variables in the results section. They contain the username, the condition, the gender and birthdate of the user, the code he received on his informed consent form, an email address, and a debriefed field. The methods defined within the User class are mainly used for communication with the Controller class, with the exception of the undo() function which removes the last entered response.



(a) The result of get_partial_map() function with Node D from the example map from figure 20a

(b) The result of get_partial_map() function with Node G from the example map from figure 20a

Figure 21: Example for using the get_partial_map() function of the ConceptMap class

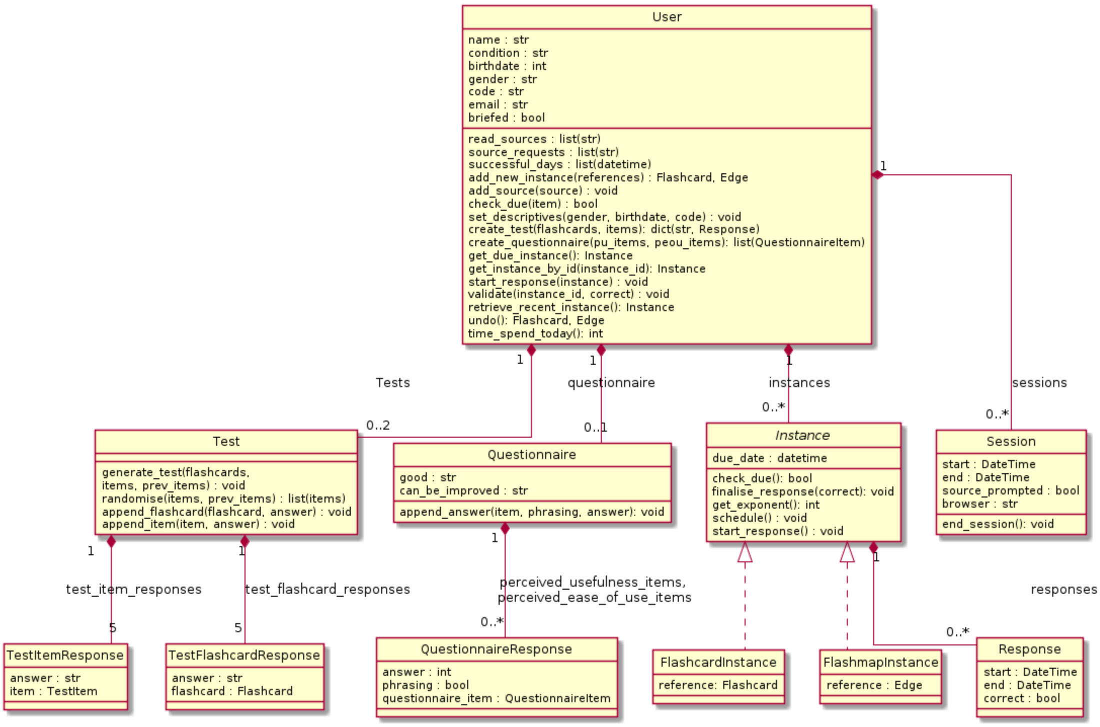


Figure 22: A UML class diagram illustrating the User class and its embedded classes. For readability, the TestItem, QuestionnaireItem, Flashcard and Edge classes are referred to inline within the attributes instead of as separate classes with aggregation links.

Username First and foremost, every user has a unique username which can be used to log in to the application. This name is chosen by the user himself, so he can decide to use his proper name or use an alias to remain anonymous. Even so, within the released data this field is removed in order to safeguard the identities of the user.

Condition This field determines whether the user is partaking in the "FLASHCARD" group (the control group) or the "FLASHMAP" group (the experimental group). This field is set when the user registers a new account by the formula $len(users)$ mod 2, which entails that every new user is assigned to the opposite group relative to the user before. This is in order to ensure that the initial users are equally divided over both groups.

Gender The gender field of the user is included in order to check after the experiment whether the distribution of genders is equal within both experimental conditions. This variable is prompted before the pretest.

Birthdate The birthdate field of the user is included in order to check after the experiment whether the age distributions of both experimental conditions are the same. This variable is prompted before the pretest.

Code Before the start of the experiment, every student participating had to sign an informed consent form together with a parent or caretaker in accordance with the Ethics Committee at the University of Twente. To ensure that every user in the system corresponded with students who handed in a double signed form without the user having to enter his own name into the system, every form contained a code which was prompted towards the user before the pretest.

Email At the end of the questionnaire, the user was prompted whether he wanted to participate in an interview. If this was the case, he could fill in his email address here in order to be contacted at a later date. This variable is also ommitted in the published data.

Debriefed This field is a simple boolean value indicating whether the user has been debriefed. It initiated with a False value, and was set to True when the server received a "DEBRIEFING-RESPONSE" message from the client (see figure 17 on page 43).

Sessions

A Session object represents the time between the user logs in and out. This is represented by a *start* and *end* value, indicating the time interval and the moment that the user was active. Additionally, the Session object has a variable *source_prompted*, indicating whether the user was prompted to read a section within the instructional material. The object finally contains a string *browser*, which is the string retrieved from navigator.platform in the client window.

Instances

The instances class is the most relevant class for the functioning of the flashcard system, containing a record of responses and the scheduling function. The name instance is used in order to distinguish between an abstract Flashcard or Edge, which is the same for each user, and the specific instance of this idea within the memory of a user. An Instance object can be either a FlashcardInstance or a FlashmapInstance, depending of the experimental condition of the user.

Attributes Each Instance object has a *due_date* and *reference* attribute. The *due_date* attribute indicates when this instance is due for review by the user, and initiates at the current date and time. This date is set by the scheduling function, which is elaborated below. The reference attribute contains either a Flashcard or an Edge object. As already indicated in the previous chapter, each time the user has no more due instances a new instance is created referring to a new item. The *reference* field refers to either a Flashcard or an Edge, depending on the specific subclass of Instance.

Responses The Response class represents each individual time the user reviews an instance, containing a *start* field for when the Flashcard or Edge was prompted, an *end* field for when the server received the response from the user, and a *correct* field for whether the user was able to think of the correct answer or to_node when being prompted.

Schedule The scheduling algorithm uses two different methods from Instances, namely get_exponent() and schedule(), and is illustrated in figure 23. In the Design frameworks chapter on page 47, it is described that to calculate the interval until the next review, one needs the number of correct responses since the last incorrect response. This is done by the get_exponent() function, which loops through the responses in descending order of *end* date, increasing a counter (exp, initiated with value 1), until a response with a False *correct* value is found. The schedule() function then takes 5^{exp} seconds as the interval until the next review of the instance as specified in the Adaptive sequencing section on page 51. Examples:

- When there are no responses, the interval is $5^{1+0} = 5$ seconds;
- When there are two correct responses, the interval is $5^{1+2} = 125$ seconds;
- When there are two correct responses, followed by one incorrect response and then three correct responses, the interval is $5^{1+3} = 625$ seconds.

This interval is then added together with the *end* value of the last response and sets this as the new *due_date* value.

Tests and Questionnaire

Finally, each User also contains Test entries and a Questionnaire entry, which involve response entries and constructor functions.

Responses The responses consist either of FlashcardItemResponses and TestItemResponses, or QuestionnaireResponses, which all refer to a database item (a Flashcard, TestItem or QuestionnaireItem) and contain an answer string or likert-scale value. Each QuestionnaireItem also contains an entry indicating which *phrasing* was used when prompting the item, and a Questionnaire also contains string entries for what the user thought was good about the application, and what could be improved.

Constructors are used to create randomly generated Test and Questionnaire objects based on the items in the database. The Test constructor creates a random set of 5 to be filled in FlashcardResponses and a random set of 5 TestItemResponses, which are used as the Knowledge and Comprehension questions. The constructor can also be given a list of Flashcards and TestItems to be excluded from the selection. This makes it possible to generate posttest which do not contain any items present within the pretest. The Questionnaire constructor creates a

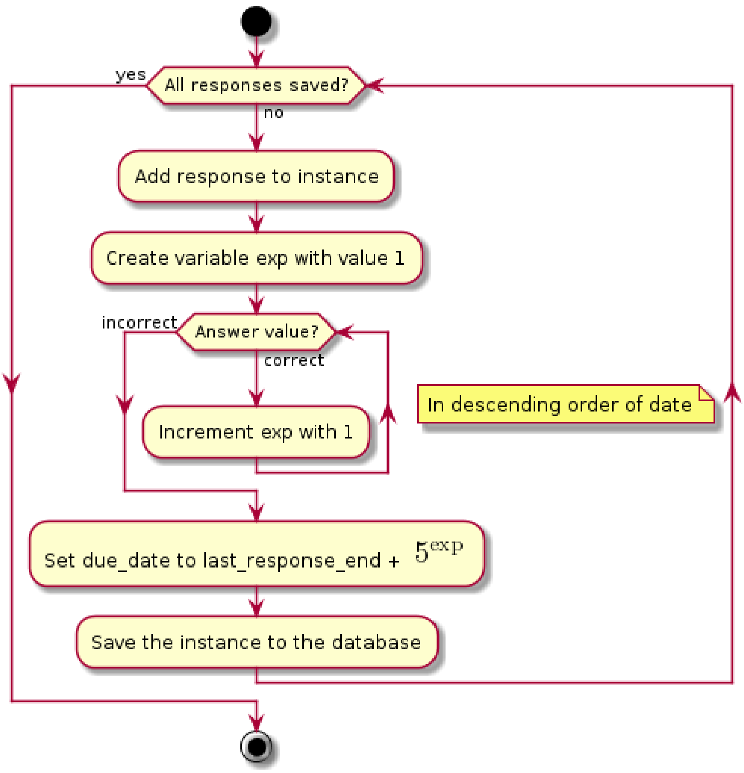


Figure 23: An UML activity diagram showing the scheduling and saving of a list of responses within instances

shuffled set of Perceived Usefulness items with randomly assigned phrasings, a shuffled set with the same Perceived Usefulness items but with opposite phrasings, and similar two sets containing Perceived Ease of Use items.

Unittests

In order to remove programming errors and unexpected behaviour, all server methods are rigorously tested using unittest, which can be found on `https://github.com/mcvdenk/MasterThesis-Software/tree/master/server/unittests`.

Client design and development

Within this chapter, the front end of the webapplication and its design choices are expounded. Firstly, the general page elements are explained, which are mainly defined within the HTML and CSS of the application (see the index.html and style.css within the Source files of the client appendix on page 108. Sequentially, the learning process interface is elaborated in a separate section, since this encompasses the main functionality of the application. This process is mainly defined within client.js (see the client.js section, also within the Source files of the client appendix). The complete source code for the client is also available on `https://github.com/mcvdenk/MasterThesis-Software/tree/master/client`. Finally, the other views are described, such as the login screen or the learning progress overview. All full screenshots referred to within this chapter are included in the Screenshots of the client appendix on page 121.

Page elements

Each page is represented by the same HTML file defining 4 different page elements, which are the navigation menu, the instructions panel, the main viewer, and a button panel. Within the different views of the application, they generally preserve the same functionality and layout, and will be explained below after the description of the colour scheme.

Navigation menu

The navigation appears as a centered div at the top of the screen, displaying buttons for the pages of the applications plus a button to contact the developer for help. An image of this menu is included in figure 24.

Instructions panel

The instructions panel is the next element is placed below the navigation menu, and is reserved for providing the user with extra instructions where needed. It does not have a background colour, but it does have a fixed height in order to keep all elements at the same place independent of the length of the instruction. The instruction has a centric text-alignment.

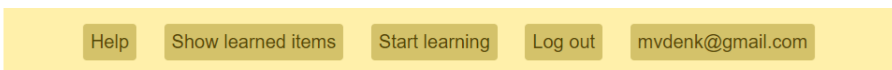


Figure 24: The navigation menu

Main viewer

The main viewer is the center element, and expands from the instruction panel to the button panel. Within this container, the main content of the specific view is displayed, such as the flashcard or concept map, the questionnaire, or the login form. In order to stand out from the rest of the page, it has a separate background with rounded corners. The background colour is somewhat lighter in comparison to the general background colour in order for the text to be better readable. The main viewer is also the container for visjs, which is a javascript library for rendering graphs in browsers.

Visjs Since the content contained within the graph is dynamic because of the partial maps returned from the server, generated automatic layouts of graphs are necessary. Visjs is capable of two models for automatic layout, namely hierarchical and force-directed. As described in the Concept map construction design features section on page 47, the initial idea was to render the graphs as hierarchical. Upon trying this with different subgraphs however it was found that automatic assignment for the different nodes on different hierarchical levels was not correctly done by visjs. This is mainly due to the two options for hierarchical layouts, namely hubcentered and directed. The idea of a hubcentered hierarchy is that the levels of the nodes within the hierarchy are based on the amount of other nodes directly or indirectly linked to this node. This works especially well for tree graphs, but because of the cross-links a concept map is not a tree graph. The other option, directed hierarchy, should make advantage of the directed edges by determining the levels of the nodes based on the direction of the edges. Unfortunately, this is implemented within visjs as only the root and the leaves being determined whether there are only incoming or outgoing edges, whereas the rest of the nodes are still placed based on the hubcentered layout, unlike in other graph layout engines such as DOT.

Because this rendering leads to more confusing graphs, the force-directed layout was chosen instead, despite this resulting in a more cyclical graphs common in other visualisation techniques such as mind maps. This layout engine attempts to position the nodes in such a way that all edges are about equally long and there are as few crossing edges as possible. This is done by assigning forces among the set of edges and the set of nodes, for example for having all nodes an inverse gravity force and all edges a spring force.

The other options include options for assigning colours fitting within the existing colour scheme, and for the user being able to reposition nodes if for example the edge labels are not readable because of overlapping with other edges.

Button panel

Finally, within the footer of the page, a button panel is included. Here the user can choose to for example show the correct answer to a flashcard, or confirm that he has read a certain section within the instructional material. The layout of this panel is exactly the same as that of the navigation menu.

Learning process

The core functionality of the client is reviewing the user instances. In general, every time an instance is reviewed, first the question or incomplete flashmap is prompted, the user thinks of the correct answer, the client shows the correct answer, and finally the user indicates whether his answer was correct or incorrect. Furthermore, the client can prompt whether the user has read a certain section from the textbook, indicate that the user is finished with learning for today, or state that there are no more instances left to review. Finally, the user can also undo his last submitted response. These use cases are elaborated below.

Read source

When a new user starts learning, he will first be asked whether he has read section 13.1 from the instructional material (see figure 27). Within the main viewer the question "Did you read section 13.1 already? If no, read this now." is displayed in Dutch. The user can then press the "Read" button in the button panel, which will lead to prompting the first instance. This screen is simular for each subsequent section prompt.

Prompt

The prompt of an instance is dependent on the experimental condition of the user. If the user is a flashcard user, he will see the prompt such as in figure 28. The main viewer contains the specific flashcard question, and the button panel contains a button with the label "Show answer". The flashmap users get to see a partial incomplete flashmap within the main viewer (figure 29), which they can drag around and zoom in and out on. The cues which have to be retrieved are indicated by orange empty nodes. The button panel is the same for both conditions. After the user has at least responded to one instance, an "Undo" button appears left to the "Show answer" button (see figure 30), with which the user can reanswer his previous response. The instructions element also shows instructions on what the user should achieve (to retrieve the correct answer from memory).

Show answer

After the user has pressed the "Show answer" button, the show answer prompt will be shown. Flashcard users get to see the correct answer in the main viewer below the question, with "Incorrect" and "Correct" buttons in the button panel to indicate whether the correct answer could be retrieved (figure 31. Flashmap users get to see the correct answers within the previously empty nodes, which will also turn green indicating that the user retrieved them correctly (figure 32). When the user did not retrieve an answer correctly, he can click on that node, turning it red (figure 33). After the user indicated the correct and incorrect retrievals, he can click on a "Next" button in the button panel. The instructions element again contains instructions on what to do within this screen.

Finished learning and No more instances

Finally, when the user has spent 15 minutes on the system or when there are no instances left to review, the user gets to see a screen such as in figure 34. The main viewer contains information on why the user is finished. When the user is finished because there are no more instances left in the sections he already read but there are still instances available in following sections, it also shows which section the user could read for the next instance, and presents a button to continue. Finally, if the user spent 6 days on the system, this prompt will also inform him that the next day he can take the posttest and fill in the questionnaire.

Other views

Next to the main functionality described in the previous section there are also other views for accommodating the other use cases. For new users, these are the login screen, the descriptives screen, and the pretest, for regular users there are the help screen and the learning progress screen, and for the users which are finished there are the posttest, questionnaire, and debriefing screens.

Login screen

The main viewer in the login screen containing a simple form with a textfield for the username, and a submit button for logging in (figure 35). Furthermore, a text within the instructions panel refers the users to the researcher's email adress for when they require further instructions or when the logging in does not function.

Descriptives, Test and Questionnaire forms

These screens also contain basic forms, all containing questions or items and either textfields or radiobutton selection panels, depending on whether the question or item is open or closed, and a submit button at the bottom. (figures 36, 37 and 38, and 39 and 40). The date field within the descriptives form is checked to be a valid date before the user can submit. Furthermore, the questionnaire item contains an email field for when the user wants to sign up for a later interview, which is a voluntary field and can be left empty. The instructions element again provide instructions for how to fill in the forms.

Debriefing

Finally, when the user is finished using the system and filling in the posttest and questionnaire, the application presents the debriefing information (figure 41). This entails a thank you message, that the user will receive the coupon for ice cream soon, that he is able to keep using the system, that he can request his personal data gathered during the experiment from the researcher at any time, that he will receive an email for making an appointment for the interview when he filled in his email address, and that for further questions he can always send an email to the researcher's email address. When the user has read this information he can click the "Read" button.

Help

The help screen (figure 42) contains some global information about the experiment and on what conditions the user can receive the icecream coupon. It also states that the system will notify the user as soon as he is ready for today.

Learning progress

Finally, the user can request information about how much progress he made. Flashcard users are presented with how many cards are ready to be learned right now, how many are never reviewed, how many are new (less than exponent 2), how many are in the learning stage (less than exponent 6) and finally how many cards have been learned for the long term (more than exponent 6). Figure **??** shows a learning progress screen of a new flashcard user, and figure **??** an shows this overview for a user having correctly reviewed one flashcard but incorrectly reviewed another flashcard. The flashmap user is shown with a different overview, namely the part of the concept map containing the edges already reviewed by the user (figure **??**), which will expand during the use of the system.

These views can still be improved in order to better convey the progress towards a user, which would contribute to a higher self-reinforcement. However, this has not yet been implemented due to time constraints.

Part III

Research

Aims and goals for the research

Methods

Results

Quantitative results

Qualitative results

Part IV

Recommendations

Part V

Epilogue

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Appendices

Test literature history 16th and 17th century

This is not the test used as pre- and posttest within the research, but a test provided to the previous generation of students provided by the teacher.

1. Provide a Dutch word for the term ‘renaissance’. Furthermore, explain the central idea of the renaissansistic body of thoughts.
2. Indicate whether the following statements are ‘true’ or ‘false’:
   (a) The renaissance originated in the Northern and Central Italian republican citystates.
   (b) The literature from the renaissance is only a revival of classical genres.
   (c) The eventual goal of renaissance writers is imitatio.
   (d) An amount of great playwriters from the renaissance is literarily schooled within a chamber of rhetoric [*rederijkerskamer*].
3. What is the essence of humanism?
4. Read the citation below: [...]
   (a) What is the title of the book from which this citation originates and who wrote this book?
   (b) What was the goal of writing this book and why is the book still attractive to read?
5. (a) What was the reason for writing the Dutch Authorised Version of the bible [*Statenbijbel*]?
   (b) Some of the expressions we are still using come from the Dutch Authorised Version of the bible. Why was this bible, generally stated, so important for language in that time?
6. Except of imitatio writers used two other methods. Enlist the three methods in the right order and provide a description for each.
7. (a) Which poet is the great example for those who write lovepoetry in this era?
   (b) Explain what platonic love is and what this has to do with lovepoetry from question 7a and with the adjoining picture [see figure 25].
8. Which combination of terms best displays the central ideas from renaissance literature?
   (a) Learning and pleasure

(b) Antiquity and church
(c) Love and antiquity
(d) Church and pleasure

9. Provide for each of the genres of theater (tragedy, comedy, and farce [*klucht*]) a name of a matching writer and the title of a matching play.

10. Provide two differences between a tragedy and a farce.

11. Quickly after Willem-Alexander became king of the Netherlands, he visited different provinces together with Máxima. The province of Drenthe gave a small book on the occasion of this visit, containing among else the following poem: [. . .]

    (a) This poem is a sonnet. Enlist the characteristics of a sonnet regarding the form and content.
    (b) Explain how the content-related characteristic is included in the poem above.
    (c) Who was our most important sonnet writer in the 17th century?

12. (a) What is the goal of *emblematiek*? Include the term 'analogical thinking' in your answer.
    (b) Of which three parts does an emblem exist? Use the original terms/names.

13. View and read the emblem below [see figure 26] and conduct the following assignments:

    (a) Explain in your own words which analogy is made in the emblem and which lesson the writer wants to teach the reader.
    (b) With which word from the original emblem does the analogy start?

14. In the children series 'Dappere Dodo', 75 episodes were broadcasted on the Dutch TV between 1955 and 1964. The programm revolved around *Dappere Dodo*, who together with his friends Kees, Uncle Harrie, the captain, Grandfather Buiswater and Mrs Vulpen sailed around the world and experienced all kinds of adventure. 'Dodo' is in this series an appropriate name for the main person. Provide a good explanation for this.

15. The shipsjournal of Bontekoe went up in flames during a shipboard fire. Why did he write the journal again after the sea journey?

16. What does the Meertens Institute? It occupies itself with:

    (a) the study and documentation of Dutch language varation and folk culture
    (b) research into and documentation of European language and culture
    (c) collecting and documenting songs, specific from the period of the 16th and 17th century
    (d) research into dialects and socilects in European context.

Figure 25: The figure accompanying question 7b

Figure 26: The figure accompanying question 13. This figure was accompanied by the following text: "Soo lang de Roe wanckt. Veel mensche zijn deughdelijck, soo langh zy onder het kruys en verdruckinghe leven: maer als de Roede van den eers is, soo worden zy luy in den dienste Goods. Ghelijuck enen Drijf-tol, die niet meer gheslaghen of ghegispt en wort, die valt haest in onmacht ende blijft ligghen. Uit: Roemer Visscher, Sinnepoppen." In the original test a modern Dutch translation was also provided.

a2d1a05

Flashmap server Documentation

Release 1.0

M.C. van den Enk

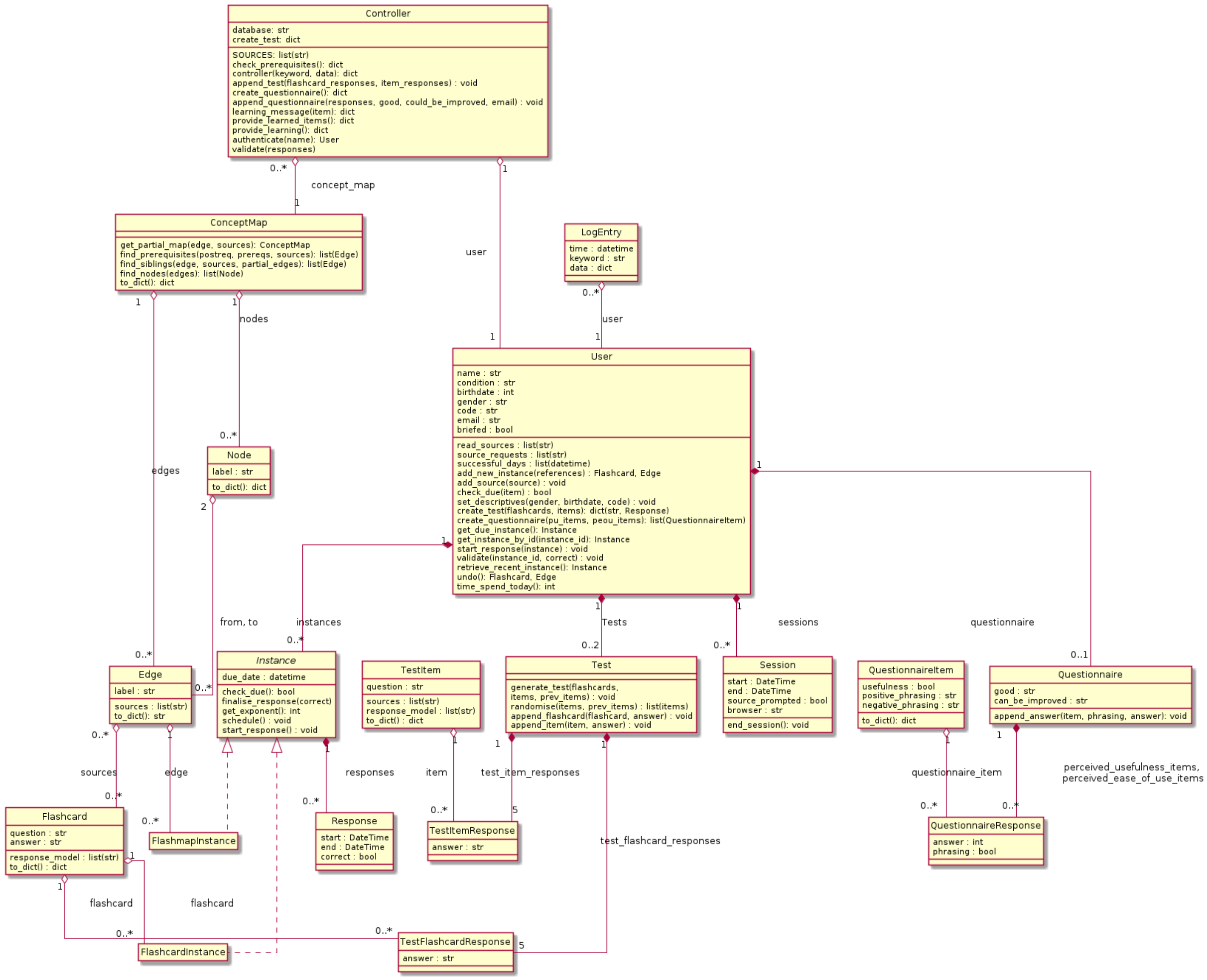
May 27, 2017

CONTENTS

CHAPTER

ONE

CLASS DIAGRAM



CHAPTER

TWO

MODULES:

2.1 concept_map module

class concept_map.**ConceptMap**(**args*, ***values*)

Bases: mongoengine.document.Document

A class representing a concept map

Variables

- **nodes** – a list of nodes (by default all existing node documents)
- **edges** – a list of edges (by default all existing edge documents)

find_nodes(*edges*)

Returns the from and to self.nodes given a list of self.edges

Parameters self.edges (*list (Edge)*) – The list of self.edges for which to find the self.nodes

Returns The list of nodes referred to in the edges

Return type list(*Node*)

find_prerequisites(*postreq*, *prereqs*, *sources*)

Return a list of parent self.edges given a certain edge from a list of self.edges, filtered by a list of sources

Parameters

- **postreq** (Edge) – The edge which is currently investigated for parent self.edges
- **prereqs** (*list (Edge)*) – A list of already found parent self.edges (starts usually empty, necessary for recursion)
- **sources** (*list (string)*) – A list of the currently read sources, self.edges which have a source not included in this list will not be included in the resulting list

Returns A list of self.edges which are prerequisites from edge

Return type list(*edge*)

find_siblings(*edge*, *sources*, *partial_edges*)

Return a list of self.edges which are siblings of the given edge and have the same label

Parameters

- **edge** (Edge) – The edge investigated for siblings
- **sources** (*list (string)*) – The sources to filter on when looking for siblings

- **partial_edges** (*list (Edge)*) – A list of self.edges for exclusion when looking for siblings

Returns A list of edges which are siblings of edge and have the same label

Return type list(*edge*)

get_partial_map(*edge*, *sources*)
Returns a concept map containing only the parent and sibling self.edges together with the referred self.nodes

Parameters

- **edge** (Edge) – The input edge
- **sources** (*list (string)*) – The list of sources to filter on

Returns A concept map containing parent and sibling self.edges of edge together with the referred self.nodes

Return type *ConceptMap*

to_dict()
Returns a dictionary representation of this object

The representation is compatible for use with vis.js, with 'self.nodes' entries containing an 'id' and 'label', and 'self.edges' entries containing an 'id', 'label', 'from', 'to', and an additional 'source' entry

Result The dictionary representation, compatible with visjs

Return type dict

2.2 controller module

class controller.**Controller**(*database*)
Bases: object

This is the class from which the program is controlled. It can be used together with the `handler` module in order to communicate with an external client over a websocket

Variables

- **database** – The mongodb to connect to
- ***concept_map*** – The concept map object containing references to nodes and edges
- **SOURCES** – All of the sources referenced to in the edges of the concept map
- ***user*** – The active user

append_questionnaire(*responses*, *good*, *can_be_improved*, *email*)
A method for appending a questionnairy to the user given responses

Parameters

- **responses** (*list (dict)*) – A list of dict objects containing the id of a `QuestionnaireItem` (key = 'id'), the phrasing (key = 'phrasing') and an answer (key = 'answer')
- **good** (*string*) – A description of what was good about the software according to the user
- **can_be_improved** (*string*) – A description of what can be improved about the software according to the user

append_test (*flashcard_responses*, *item_responses*)
A method for appending a test to the user given flashcard and item responses

Parameters

- **flashcard_responses** (*dict*) – A list of dict objects containing the id of an `Flashcard` (key = 'id') and an answer (key = 'answer')
- **item_responses** (*dict*) – A list of dict objects containing a `TestItem` (key = 'item') and an answer (key = 'answer')

authenticate (*name*)
A function to either set self.user to an existing *user.User* or to a new User based on the given name

Parameters **name** (*str*) – The self.username

check_prerequisites ()
Checks whether the self.user still has to fill in forms and returns the appropriate message

Returns A dict containing the appropriate keyword and data for this self.user

Return type dict

controller (*keyword*, *data*)
Pass data to the function corresponding to the provided keyword for the provided user

Parameters

- **keyword** (*str*) – the keyword for which function to use
- **data** (*dict (str, str or dict)*) – the data necessary for executing the function

Returns Contains the keyword and data to send over a websocket to a client

Return type dict(str, str or dict)

learning_message (*item*)
Generates a learning message for the provided instance

Parameters **instance** (`Instance`) – The instance which has to be rehearsed

Returns The message with keyword "LEARNING RESPONSE" and data containing the partial concept map or flashcard dict representation

Return type dict

provide_learned_items ()
Provides an overview of all learning

Returns A partial concept map containing all instances for this self.user or a message containing progress information

Return type dict

provide_learning ()
Provides a dict containing relevant information for learning

Provides a dict containing the keyword "NO_MORE_INSTANCES", "READ_SOURCE-REQUEST", or "LEARNING-RESPONSE" and relevant data (the source string for "READ_SOURCE-REQUEST" or either the output of `ConceptMap.to_dict()` with an added 'learning' entry or the output of `Flashcard.to_dict()` for "LEARNING-RESPONSE" with an added condition entry)

Returns A dict containing 'keyword' and the relevant 'data' described above

Return type dict

validate (*responses*)
Adds responses to certain instances

Parameters **responses** (*list (dict)*) – A list of responses containing an instance id and a boolean correctness value

2.3 edge module

class edge.**Edge** (**args*, ***values*)
Bases: mongoengine.document.Document

A class representing an edge from a concept map

Variables

- **from_node** – The parent node of the edge
- **to_node** – The child node of the edge
- **label** – A label describing the relation between from_node and to_node
- **sources** – The source where this edge is described (e.g. paragraph 13.2 from Laagland)

to_dict ()
Returns a dictionary representation of this object

It contains an 'id', 'label', 'from', 'to', and 'sources' entry

Returns The dictionary representation of this object, compatible with visjs

Return type dict

2.4 flashcard module

class flashcard.**Flashcard** (**args*, ***values*)
Bases: mongoengine.document.Document

A class representing a flashcard

Variables

- **question** – The question on the front side of the flashcard
- **answer** – The answer on the back side of the flashcard
- **sources** – The edges where this flashcard is based on
- **response_model** – A list consisting of parts of valid responses to the question (for the test matrix)

to_dict ()
Returns a dictionary representation of this object

It contains an 'id', 'question', 'answer', and 'sources' entry

Returns The dictionary representation of this object

Return type dict

2.5 flashcard_instance module

class `flashcard_instance.`**`FlashcardInstance`**(**args*, ***kwargs*)

Bases: `instance.Instance`

A class for storing responses from the flashmap system

Variables **`reference`** – The flashcard to which this instance refers

2.6 flashmap_instance module

class `flashmap_instance.`**`FlashmapInstance`**(**args*, ***kwargs*)

Bases: `instance.Instance`, `mongoengine.document.EmbeddedDocument`

A class for storing responses from the flashmap system

Variables **`reference`** – The edge from the concept map to which this instance refers to

2.7 instance module

class `instance.`**`Instance`**(**args*, ***kwargs*)

Bases: `mongoengine.document.EmbeddedDocument`

A class describing a general flash instance, which can either be a FlashmapInstance or a FlashcardInstance

Variables

- **`responses`** – A list of responses provided to this instance (an empty list by default)
- **`reference`** – A reference to either an edge in a concept map or a flashcard (defined within the subclass)
- **`due_date`** – The date this instance is due for repetition

`check_due`()

Checks whether this instance is due for repetition

Returns Whether the due datetime is earlier than the current datetime

Return type bool

`finalise_response`(*correct*)

Sets the correctness value for the final response and sets the end date to now

Parameters **`correct`** (*`bool`*) – Whether the response was correct

`get_exponent`()

Determines the exponent for the rescheduling of this instance

Returns The amount of times this instance was answered correctly since the previous incorrect answer

Return type int

`schedule`()

Reschedules this instance for review based on the previous responses

`start_response`()

Adds a new response to this instance

2.8 log_entry module

class `log_entry.LogEntry`(**args*, ***values*)

Bases: `mongoengine.document.Document`

An object representing a incoming or outgoing network message

Variables

- `user` – The user which was involved with this network message
- `keyword` – The network keyword
- `data` – The dictionary containing the necessary data
- `time` – The time that this message was received or transmitted

2.9 node module

class `node.Node`(**args*, ***values*)

Bases: `mongoengine.document.Document`

A class for representing nodes in the concept map

Variables `label` – The label appearing within the node

`to_dict`()

Returns a dictionary representation of this object

It contains an 'id' and 'label' entry

Returns The dictionary representation of this object, compatible with visjs

Return type dict

2.10 questionnaire module

class `questionnaire.Questionnaire`(**args*, ***kwargs*)

Bases: `mongoengine.document.EmbeddedDocument`

A class representing a stored questionnaire for a user

Variables

- `perceived_usefulness_items` – Responses to the perceived usefulness items from TAM
- `perceived_ease_of_use_items` – Responses to the perceived ease of use item from TAM
- `good` – A description of what was good about the software according to the user
- `can_be_improved` – A description of what could be improved according to the user

`append_answer`(*item*, *phrasing*, *answer*)

Appends an answer to an item within the questionnaire

Parameters

- `item` (`QuestionnaireItem`) – The item to which the answer refers

- **phrasing** (*bool*) – Whether the item is positively (True) phrased or negatively (False)
- **answer** (*string*) – The answer to be appended

generate_questionnaire(*pu_items*, *peou_items*)
A method to set the questionnaire items based on two sets of items

Parameters

- **pu_items** (*list (QuestionnaireItem)*) – The perceived usefulness items of TAM
- **pu_items** – The perceived ease of use items of TAM

2.11 questionnaire_item module

class questionnaire_item.**QuestionnaireItem**(**args*, ***values*)
Bases: mongoengine.document.Document

A class representing a single item on the questionnaire

Variables

- **usefulness** – Defines whether the item is part of the perceived usefulness items (True) or of the perceived ease of use items (False)
- **positive_phrasing** – The version of this item which is positively phrased
- **negative_phrasing** – The version of this item which is negatively phrased

to_dict(*phrasing*)
A method for generating a dictionary representation of this object

Parameters **phrasing** (*bool*) – Whether the positive or negative question is required

Returns The representation containing an id field, a phrasing field and a question field

Return type dict

2.12 questionnaire_response module

class questionnaire_response.**QuestionnaireResponse**(**args*, ***kwargs*)
Bases: mongoengine.document.EmbeddedDocument

A class for storing singular responses to questionnaire items

Variables

- ***questionnaire_item*** – The questionnaire item to which this answer refers
- **answer** – The value of the likert-scale rating the user gave to this item (ranges from -2 to 2)
- **phrasing** – Whether this answer refers to the positively (True) or the negatively (False) phrased version of the questionnaire_item

2.13 response module

class `response.`**`Response`**`(`**args*, ***kwargs*`)`
Bases: `mongoengine.document.EmbeddedDocument`

A class representing a singular response to an `Instance`.

Variables

- **`start`** – The moment the parent `Instance` was sent to the client
- **`end`** – The moment the answer from the client was received
- **`correct`** – Whether the answer to the `Instance` was correct (True) or incorrect (False)

2.14 session module

class `session.`**`Session`**`(`**args*, ***kwargs*`)`
Bases: `mongoengine.document.EmbeddedDocument`

A class representing a session the user was logged in

Variables

- **`start`** – The time that the user logged in
- **`end`** – The time that the user logged out
- **`source_prompted`** – Whether the user was asked to have read a certain source from SOURCES
- **`browser`** – The type of browser used to log in

`end_session``()`
Closes this session

2.15 test module

class `test.`**`Test`**`(`**args*, ***kwargs*`)`
Bases: `mongoengine.document.EmbeddedDocument`

A class representing a pre- or posttest the user filled in

Variables

- **`test_flashcard_responses`** – A list of responses to the flashcard questions on the test
- **`test_item_responses`** – A list of responses to the item questions on the test

`append_flashcard``(`*flashcard*, *answer*`)`
Adds a flashcard response to this test

Parameters

- **`flashcard`** (`Flashcard`) – The flashcard this item refers to
- **`answer`** (*`string`*) – The answer to the flashcard provided by the user

append_item (*item, answer*)
Adds an item response to this test

Parameters

- **item** – The test item this item refers to
- **answer** (*string*) – The answer to the flashcard provided by the user

generate_test (*flashcards, items, prev_flashcards=[], prev_items=[]*)
A method for creating test items for this test based on a set of given flashcards and items, using randomise()

Parameters

- **flashcards** (*list (Flashcard)*) – The flashcards to be used for the test
- **items** (*list (Item)*) – The items to be used for the test
- **prev_flashcards** (*list (Flashcard)*) – The list of flashcards to be excluded from this test
- **prev_items** (*list (TestItem)*) – The list of items to be excluded from this test

randomise (*items, prev_items*)
A method for taking five random items in a random order from the provided list of items without the items in the previous items

Parameters

- **items** (*list (Flashcard) or list (TestItem)*) – The complete list of items
- **prev_items** (*list (Flashcard) or list (TestItem)*) – The list of items to be excluded from the result

Result A sample of five items from items not included in prev_items

Return type list(FlashcardResponse) or list(*TestItemResponse*)

2.16 test_flashcard_response module

class test_flashcard_response.**TestFlashcardResponse** (**args, **kwargs*)
Bases: mongoengine.document.EmbeddedDocument

An answer for a flashcard item within a pre- or posttest

Variables

- **answer** – The answer provided by the user
- **reference** – The flashcard to which this response refers to
- **scores** – The list of correct response elements in the answer

2.17 test_item module

class test_item.**TestItem** (**args, **values*)
Bases: mongoengine.document.Document

A class representing an item from a pre- or posttest

Variables

- **question** – The question for this item
- **sources** – A list of sources relevant to this question
- **response_model** – A list of the parts of a valid answer used for the test matrix

to_dict()

A method for generating a dictionary representation of this object

Returns The representation containing an id field and a question field

Return type dict

2.18 test_item_response module

class test_item_response.**TestItemResponse**(**args*, ***values*)

Bases: mongoengine.document.Document

A class representing singular answers to test items

Variables

- **answer** – The answer to item provided by the user
- **reference** – The specific item this response refers to
- **scores** – The list of correct response elements in the answer

2.19 user module

class user.**User**(**args*, ***values*)

Bases: mongoengine.document.Document

A class representing a user

Variables

- **name** – The username
- **type** – string
- **condition** – The condition of the user (“FLASHMAP” or “FLASHCARD”)
- **birthdate** – The birthdate of the user
- **read_sources** – A list of read sources by the user
- **gender** – The gender of the user (can be either ‘male’, ‘female’, or ‘other’)
- **code** – The code from the user’s informed consent form
- **tests** – The pre- and posttest
- *questionnaire* – The questionnaire
- **instances** – A list of instances storing the flashmap/flashcard data for the user
- **sessions** – A list of past sessions for this user
- **email** – The email address for this user
- **source_requests** – The days that the user was prompted a source request
- **successful_days** – The days that the user successfuly completed a session

- **debriefed** – Whether the user already got the briefing after the experiment

add_new_instance (*references*)
Adds a new Instance to this user

Parameters **reference** (*list (Flashcard or Edge)*) – A set of flashcards or edges for which to add a new instance

Returns The reference for which a new instance was added

Return type *Flashcard* or *Edge*

add_source (*source*)
Adds a read source to self

Parameters **source** (*string*) – The source to be added

check_due (*item*)
Checks whether the provided item is due for review

Parameters **item** (*Edge or Flashcard*) – The item to which the checked instance refers to

Returns Whether the provided item is due for review

Return type bool

create_questionnaire (*pu_items*, *peou_items*)
A method for creating a new questionnaire

Parameters

- **pu_items** – A list of perceived usefulness items
- **peou_items** – A list of perceived ease of use items

Returns A randomised list of questionnaire items

Return type list(*QuestionnaireItem*)

create_test (*flashcards*, *items*)
A method for creating a new test with unique questions

Parameters

- **flashcards** (*list (Flashcard)*) – A list of flashcards from the database
- **items** (*list (TestItem)*) – A list of items from the database

Returns A dict containing a list of FlashcardResponses and TestItemResponses

Return type dict(string, *Flashcard* or *TestItem*)

get_due_instance ()
Returns the instance with the oldest due date

Returns Either the instance with the lowest due date or a None object

Return type *Instance*

get_instance_by_id (*instance_id*)
Retrieves an instance based on a provided instance id

Parameters **instance_id** (*ObjectId*) – The id of the instance to be requested

Returns The instance or None if no instance with instance_id exists

Return type *Instance*

retrieve_recent_instance()
Retrieves the instance most recently answered by the user

Returns The instance with the latest response.end being the most recent of all instances

Return type *instance*

set_descriptives(*birthdate*, *gender*, *code*)
A method for setting the descriptives of the user

Parameters

- **birthdate** (*DateTime*) – The provided birthdate of the user
- **gender** (*string*) – The gender of the user (can be either 'male', 'female', or 'other')
- **code** (*string*) – The code from the informed consent form

time_spend_today()
A method for calculating the amount of seconds the user has spend on practicing flashcards

Returns The amount of seconds between every start and end of all responses of all instances of today

Return type int

undo()
Removes the response last submitted by the user, reschedules the respective instance, and returns the referred flashcard or edge

Returns The flashcard or edge referred to by the instance with the latest response

Return type *Flashcard* or *Edge*

validate(*instance_id*, *correct*)
Finalises a `Response` within an existing `Instance`

Parameters

- **instance_id** – The id of the instance which the response refers to
- **correct** (*boolean*) – Whether the response provided by the user was correct or not

PYTHON MODULE INDEX

INDEX

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T

U

V

Source files of the client

index.html

../software/client/index.html

```html
<!DOCTYPE html>
<html>
    <head>
        <title> Flashmaps </title>
        <link rel="stylesheet" type="text/css" href="vis/dist/vis.css" />
        <link rel="stylesheet" type="text/css" href="style.css" />
        <script src="vis/dist/vis.js"></script>
        <script src="client.js"></script>
    </head>
    <body>
        <div id="wrapper">
            <header>
                <nav style="visibility:hidden">
                    <a href="#" onclick="help()">Help</a>
                    <a href="#" onclick="view_learned()">Show learned items</a>
                    <a href="#" onclick="learn()">Start learning</a>
                    <a href="#" onclick="logout()">Log out</a>
                    <a href="mailto:mvdenk@gmail.com">mvdenk@gmail.com</a>
                </nav>
                <div id="instructions"> <p>Helaas werkt de applicatie niet in deze browser, je hebt een modernere browser nodig.</p> </div>
            </header>
            <div id="mycontainer" style="visibility:hidden">
                <h3> Login </h3>
                Username:
                <input id="username" type="text" name="username"
                    onkeydown="if (event.keyCode == 13) authenticate()" />
                <a href="#" onClick="authenticate()">Log in</a>
            </div>
            <footer>
                <div id="panel"> </div>
            </footer>
        </div>
    </body>
</html>
```

style.css

../software/client/style.css

```
* {
    margin:0;
    padding:0;
    font-family: Sans-serif;
    color: #554600;
}

html, body {
    min-height: 100%;
    background: #FFF0AA;
}

#wrapper {
    padding-top: 120px;
    padding-bottom: 90px;
    position: absolute;
    top: 0;
    bottom: 0;
    left: 0;
    right:0;
}

#mycontainer {
    background: rgba(255, 255, 255, 0.3);
    text-align: center;
    min-height: 100%;
    margin: auto;
    margin-top: 10px;
    margin-bottom: 10px;
    width: 80%;
    padding: 10px;
    border-radius: 5px;
}

#mycontainer p {
    max-width: 30em;
    margin: auto;
    margin-top: 1em;
    text-align: left;
}

hr {
    max-width: 30em;
    margin: auto;
    margin-top: 1em;
}

header {
    text-align: center;
    margin-top: -100px;
    height: 100px;
}

a {
    display: inline-block;
    background: #D4C26A;
    margin: .6em;
    padding: .4em;
    text-decoration: none;
    color: #554600;
    border-radius: .2em;
```

```
}

a:hover {
    background: #AA9739;
}

h3 {
    margin: auto;
    margin-top: 1em;
    margin-bottom: .3em;
    width: 50%;
}

footer {
    text-align: center;
    margin-bottom: -50px;
    height: 50px;
}

table {
    text-align: left;
    margin: auto;
}

table tr td {
    margin: .3em;
}

input[type=text], textarea {
    border: 2px solid;
    color: #806D15;
    background: #D4C26A;
    outline: none;
    padding: .4em;
}

input[type=text]:focus, textarea:focus {
    background: #FFF0AA;
}

#instructions p {
    margin: 5px;
    width: 80%;
    margin: auto;
}

#instructions a {
    display: inline;
    background: 0;
    font-weight: bold;
    margin: 0;
    padding: 0;
}

#instructions a:hover {
    color: #805C15;
```

client.js

../software/client/client.js

```
var uname = "";
var cont = "mycontainer";
var ws = new WebSocket("ws://128.199.49.170:5678");
var network
var nodes
var edges
var map
var options = {
    nodes: {
        shape: 'box',
        color: {
            border: "#554600",
            background: "#D4C26A",
            highlight: {
                border: "#554600",
                background: "#AA9739"
            }
        },
        font: {
            color: "#554600"
        }
    },
    edges: {
        arrows: {
            to: {enabled: true}
        },
        color: {
            color: "#554600",
            highlight: "#554600"
        },
        font: {
            color: "#554600"
        }
    },
    interaction: {
        selectable: true,
        dragNodes: true
    }
//    physics : {barnesHut: {avoidOverlap: 1}}
};
var show_undo = false;
var question = "";
var answer = "";
var fc_id = "";
var logged_in = false;

ws.onopen = function (event) {
    document.getElementById("instructions").innerHTML = "<p>Je kunt hier inloggen door een al bestaande gebruikersnaam in te vullen, of een nieuw account aanmaken door een zelbedachte, nieuwe gebruikersnaam in te vullen. Als dit niet lukt, stuur dan een email naar <a href='mailto:mvdenk@gmail.com'>mvdenk@gmail.com</a>.</p>";
    document.getElementById(cont).style.visibility = "visible";
    document.getElementById("username").focus();
}

ws.onclose = function(event) {
    if (logged_in) {
        if (!alert("Connection lost.")) window.location.reload();
    }
```

```
}

function authenticate() {
    uname = document.getElementById("username").value;
    console.log(uname);
    var msg = {
        keyword: "AUTHENTICATE-REQUEST",
        data: {
            name: uname,
            browser: navigator.platform
        }
    }
    ws.send(JSON.stringify(msg));
}

ws.onmessage = function (event) {
    var msg = JSON.parse(event.data);
    console.log(msg);
    if (uname != "questionnaire") logged_in = true;

    switch(msg.keyword) {
        case "ACTIVE_SESSIONS":
            logged_in = false;
            break;
        case "MAP-RESPONSE":
            show_map(msg.data);
            break;
        case "AUTHENTICATE-RESPONSE":
            show_menu();
            help();
            break;
        case "LEARNED_ITEMS-RESPONSE":
            if (msg.condition == "FLASHMAP") {
                coloured_map = colourise_progress(msg.data);
                show_map(coloured_map);
            }
            else if (msg.condition == "FLASHCARD") {
                show_flashcard_progress(msg.data);
            }
            break;
        case "LEARN-RESPONSE":
            if (msg.condition == "FLASHMAP") {
                show_map(flashmap(msg.data, msg.time_up, msg.successful_days));
                break;
            }
            else if (msg.condition == "FLASHCARD") {
                show_card(msg.data, msg.time_up, msg.successful_days);
                break;
            }
        case "NO_MORE_INSTANCES":
            done_learning(msg.data, msg.successful_days);
            break;
        case "READ_SOURCE-REQUEST":
            prompt_source_request(msg.data);
            break;
        case "DESCRIPTIVES-REQUEST":
            ask_descriptives();
            break;
        case "TEST-REQUEST":
            test(msg.data);
            break;
        case "QUESTIONNAIRE-REQUEST":
```

```
            questionnaire(msg.data);
            break;
        case "DEBRIEFING-REQUEST":
            debriefing();
            break;
    }
}

function ask_descriptives() {
    document.getElementById("panel").innerHTML = "";
    document.getElementById("instructions").innerHTML = "Voer hier je algemene gegevens in. Ben je je code kwijt? Stuur dan even een email met je gebruikersnaam en echte naam naar mvdenk@gmail.com";
    document.getElementById(cont).innerHTML = " \
        <h3> Wat is je geslacht? </h3> \
        <table> \
        <tr> \
        <td> <input type='radio' name='gender' value='male' checked/> </td><td> Mannelijk </td> \
        </tr><tr> \
        <td> <input type='radio' name='gender' value='female' /> </td><td> Vrouwelijk </td> \
        </tr><tr> \
        <td> <input type='radio' name='gender' value='other' /> </td><td> Anders </td> \
        </tr> \
        </table> \
        <h3> Wat is je geboortedatum? </h3> \
        <input type='text' name='birthdate' id='birthdate' /> <br /> (dd-mm-yyyy) \
        <h3> Wat is de code vermeld op de toezeggingsverklaring? </h3> \
        <input type='text' name='code' id='code' /> <br /> \
        <a href='#' onClick='send_descriptives()'>Verstuur</a> \
        <div id='invalid' />";
}

function send_descriptives() {
    msg = {keyword: "DESCRIPTIVES-RESPONSE", data: {gender: "male", birthdate: 0}};
    var genderbuttons = document.getElementsByName('gender');
    for (i = 0; i < genderbuttons.length; i++) {
        if (genderbuttons[i].checked) msg.data.gender = genderbuttons[i].value;
    }
    msg.data.code = document.getElementById('code').value;
    datestr = document.getElementById('birthdate').value;
    var parts = datestr.split("-");
    if (parts.length != 3
            || parseInt(parts[2], 10) < 1900 || parseInt(parts[2], 10) > new Date().getFullYear()
            || parseInt(parts[1], 10) < 1    || parseInt(parts[1], 10) > 12
            || parseInt(parts[0], 10) < 1    || parseInt(parts[0], 10) > 31) {
       document.getElementById('invalid').innerHTML = "INVALID DATE"
       return
    }
    msg.data.birthdate = new Date(parseInt(parts[2], 10), parseInt(parts[1], 10) - 1, parseInt(parts[0], 10));
    if (msg.data.birthdate > new Date()) document.getElementById(cont).innerHTML += "INVALID DATE";
    else ws.send(JSON.stringify(msg));
}

function test(data) {
```

```
    document.getElementById("panel").innerHTML = "";
    document.getElementById("instructions").innerHTML = "<p> Probeer de
        onderstaande toets zo goed mogelijk in te vullen. Je mag vragen overslaan
        als je de antwoorden niet weet. Als dit de eerste toets is en je hebt de
        papieren versie al gemaakt kun je de toets overslaan door hem leeg te
        versturen. </p>"
    document.getElementById(cont).innerHTML = ""
    for (i = 0; i < data.flashcards.length; i++) {
        document.getElementById(cont).innerHTML += " \
            <h3>" + data.flashcards[i].question + "</h3> \
            <textarea rows='4' cols='50' class='test' name='flashcard' id='
                flashcard" + data.flashcards[i].id + "' />";
    }
    for (i = 0; i < data.items.length; i++) {
        document.getElementById(cont).innerHTML += " \
            <h3>" + data.items[i].question + "</h3> \
            <textarea rows='4' cols='50' class='test' name='item' id='item" + data
                .items[i].id + "' />";
    }
    document.getElementById(cont).innerHTML += "<br /><a href='#' onClick='
        send_test_results()'>Verstuur</a>";
}

function send_test_results() {
    msg = {keyword: "TEST-RESPONSE", data: {flashcard_responses : [],
        item_responses : []}}
    var flashcards = document.getElementsByName('flashcard');
    for (i = 0; i < flashcards.length; i++) {
        msg.data.flashcard_responses.push(
            {id : flashcards[i].id.slice(9), answer : flashcards[i].value});
    }
    var items = document.getElementsByName('item');
    for (i = 0; i < items.length; i++) {
        msg.data.item_responses.push(
            {id : items[i].id.slice(4), answer : items[i].value});
    }
    ws.send(JSON.stringify(msg));
}

function questionnaire(data) {
    document.getElementById("panel").innerHTML = "";
    document.getElementById("instructions").innerHTML = "<p>Hieronder staan
        stellingen waarbij je aan kunt geven of je het er mee eens of oneens bent.
         Dit is voor mij om te kunnen bepalen of je het flashcard systeem nuttig
        vond en makkelijk te gebruiken.</p>";
    container = document.getElementById(cont);
    container.innerHTML = "";
    container_text = "";
    var form = "";
    for (i = 0; i < data.questionnaire.length; i++) {
        if (data.questionnaire[i].phrasing == "positive") form = "+";
        else form = "-";
        item_text = " \
            <h3>" + data.questionnaire[i].question + "</h3> \
            <table style='text-align:center;'> \
                <tr> \
                    <td>Zeer mee oneens</td><td>Mee oneens</td><td>Noch mee eens,
                        <br />noch mee oneens</td><td>Mee eens</td><td>Zeer mee
                        eens</td> \
                </tr><tr>";
        for (j=-2; j <= 2; j++) {
```

```
            item_text += "<td><input type='radio' class='item' name='"+form+data.questionnaire[i].id+"' value='"+j+"' /></td>";
        }
        item_text += "</tr></table>";
        container_text += item_text;
    }
    container_text += " \
        <h3>Wat vond je goed aan het flashcard systeem?</h3> \
        <textarea rows='4' cols='50' class='questionnaire' name='goed' id='goed'></textarea> \
        <h3>Wat zijn eventuele verbeteringen die gemaakt zouden kunnen worden?</h3> \
        <textarea rows='4' cols='50' class='questionnaire' name='kan_beter' id='kan_beter'></textarea>";
    container_text += "<br /><p>Als je bereid bent om later ge&iuml;nterviewd te worden over het flashcard systeem, vul dan hieronder je emailadres in.</p> \
                    <input type='text' id='email'/>";
    container_text += "<br /><a href='#' onClick='send_questionnaire_results()'>Verstuur</a>";
    container.innerHTML = container_text;
}

function send_questionnaire_results() {
    msg = {keyword: "QUESTIONNAIRE-RESPONSE", data: {responses : [], goed: "", kan_beter: "", email: ""}}
    var q_item = document.getElementsByClassName('item');
    for (i = 0; i < q_item.length && q_item[i].checked; i++) {
        var phrasing = 'negative'
        if (useful[i].name.charAt(0) == '+') var phrasing = 'positive'
        msg.data.responses.push({id: useful[i].name.slice(1), answer: useful[i].value, phrasing: phrasing});
    }
    msg.data.good = document.getElementById("goed").value;
    msg.data.can_be_improved = document.getElementById("kan_beter").value;
    msg.data.email = document.getElementById("email").value;
    console.log(JSON.stringify(msg));
    ws.send(JSON.stringify(msg));
}

function show_map(map) {
    // provide the data in the vis format

    nodes = new vis.DataSet(map.nodes);
    edges = new vis.DataSet(map.edges);

    var graph = {
        nodes: nodes,
        edges: edges
    };

    var container =  document.getElementById(cont);
    container.innerHTML = "";
    container.style= "height:100%";

    // initialize your network!
    network = new vis.Network(container, graph, options);

    network.on('click', function(properties) {
        for (i=0; i < map.edges.length; i++) {
            if ('correct' in map.edges[i] && properties.nodes[0] == map.edges[i].to) {
```

```
                map.edges[i].correct = !map.edges[i].correct;
                if (map.edges[i].correct) {
                    edges.update([{ id: map.edges[i].id, color: {color: "#0F640F", highlight: "#0F640F"}, font: {color: "#0F640F"}}])
                    nodes.update([{ id : map.edges[i].to, color: {border: "#0F640F", background: "#55AA55", highlight: {border: "#0F640F", background: "#55AA55"}}, font: {color: "#0F640F"}}]);
                }
                else {
                    edges.update([{ id: map.edges[i].id, color: {color: "#550000", highlight: "#550000"}, font: {color: "#550000"}}])
                    nodes.update([{ id : map.edges[i].to, color: {border: "#550000", background: "#AA3939", highlight: {border: "#550000", background: "#AA3939"}}, font: {color: "#550000"}}]);
                }
            }
        }
    });
}

function show_menu() {
    document.getElementById("instructions").innerHTML = "";
    document.getElementById(cont).innerHTML = "";
    document.getElementsByTagName("nav")[0].style.visibility = "visible";
}

function colourise_progress(data) {
    document.getElementById("panel").innerHTML = "";
    return data
}

function show_flashcard_progress(data) {
    document.getElementById("panel").innerHTML = "";
    document.getElementById(cont).innerHTML = " \
        <p> Klaar om nu geleerd te worden: " + data.due +" </p> \
        <p> Nog niet gezien: " + data.not_seen + " </p> \
        <p> Nieuw: " + data.new + " </p> \
        <p> Lerende: " + data.learning + " </p> \
        <p> Geleerd: " + data.learned + " </p>"
}

function show_card(data, time_up, successful_days) {
    document.getElementById("instructions").innerHTML = "<p> Probeer de onderstaande vraag te beantwoorden </p>";
    if (time_up) {
        if (successful_days < 6) {
            document.getElementById("instructions").innerHTML = "<p style='color: red;'> Je hebt vandaag 15 minuten geleerd, nog "+ (6 - successful_days).toString() +" dagen te gaan. </p>";
        }
        if (successful_days == 6) {
            document.getElementById("instructions").innerHTML = "<p style='color: red;'> Je hebt vandaag 15 minuten geleerd, kom morgen terug voor de laatste kennistoets en de enquete. </p>";
        }
    }
    question = data.question;
    answer = data.answer;
    fc_id = data.id;
    document.getElementById(cont).innerHTML = question;
```

```
    if (show_undo) document.getElementById("panel").innerHTML = "<a href='#' onclick='undo()'> Undo </a> <a href='#' onclick='show_answer_fc()'> Toon antwoord </a>";
    else document.getElementById("panel").innerHTML = "<a href='#' onclick='show_answer_fc()'> Toon antwoord </a>";
}

function show_answer_fc() {
    document.getElementById("instructions").innerHTML = "<p> Geef aan of het door jou bedachte antwoord correct of incorrect was </p>";
    document.getElementById(cont).innerHTML += "<br><br>" + answer;
    document.getElementById("panel").innerHTML = "<a href='#' onclick='validate_fc(false)'> Incorrect </a><a href='#' onclick='validate_fc(true)'> Correct </a";
}

function flashmap(data, time_up, successful_days) {
    document.getElementById("instructions").innerHTML = "<p> Probeer te bedenken wat er in de oranje lege velden moet komen te staan. </p>";
    if (time_up) {
        if (successful_days < 6) {
            document.getElementById("instructions").innerHTML = "<p style='color:red;'> Je hebt vandaag 15 minuten geleerd, nog "+ (6 - successful_days).toString() +" dagen te gaan. </p>";
        }
        if (successful_days == 6) {
            document.getElementById("instructions").innerHTML = "<p style='color:red;'> Je hebt vandaag 15 minuten geleerd, kom morgen terug voor de laatste kennistoets en de enquete. </p>";
        }
    }
    question = data.question;
    map = data;
    for (i = 0; i < map.edges.length; i++) {
        if (map.edges[i].learning) {
            map.edges[i].color = "orange";
            for (j = 0; j < map.nodes.length; j++) {
                if (map.edges[i].to == map.nodes[j].id) {
                    map.nodes[j].color = {background : "orange"};
                    map.nodes[j].true_label = map.nodes[j].label;
                    map.nodes[j].label = "______";
                }
            }
        }
    }
    if (show_undo) document.getElementById("panel").innerHTML = "<a href='#' onclick='undo()'> Undo </a> <a href='#' onclick='show_answer_fm()'> Toon antwoord </a>";
    else document.getElementById("panel").innerHTML = "<a href='#' onclick='show_answer_fm()'> Toon antwoord </a>";
    return map;
}

function show_answer_fm() {
    document.getElementById("instructions").innerHTML = "<p> Geef aan of jouw antwoord goed of fout was. Als je op de velden klikt, veranderen ze van kleur, waarbij groen een goed antwoord is en rood een fout antwoord. </p>";
    var index
    for (i = 0; i < map.edges.length; i++) {
        if (map.edges[i].learning) {
            for (j=0;j < map.nodes.length; j++) {
```

```
                if (map.edges[i].to == map.nodes[j].id) index = j;
            }
            edges.update([{ id: map.edges[i].id, color: {color: "#0F640F", highlight: {color: "#0F640F"}}, font: {color: "#0F640F"}}])
            nodes.update([{id: map.edges[i].to, color: {border: "#0F640F", background : "#55AA55"}}]);
            nodes.update([{id: map.edges[i].to, label: map.nodes[index].true_label}]);
            map.edges[i].correct = true;
        }
    }
    document.getElementById("panel").innerHTML = "<a href='#' onclick='validate_fm()'> Volgende </a>";
}

function view_learned() {
    var msg = {keyword: "LEARNED_ITEMS-REQUEST", data: {}};
    ws.send(JSON.stringify(msg));
}

function undo() {
    var msg = {keyword: "UNDO", data: {}};
    ws.send(JSON.stringify(msg));
    show_undo = false;
}

function validate_fc(correct) {
    var msg = {keyword: "VALIDATE", data: {responses: [{}]}};
    msg.data.responses[0].id = fc_id;
    msg.data.responses[0].correct = correct;
    ws.send(JSON.stringify(msg));
    show_undo = true;
}

function validate_fm() {
    var msg = {keyword: "VALIDATE", data: {}};
    var responses = [];
    for (i = 0; i < map.edges.length; i++) {
        if (map.edges[i].learning) responses.push({id: map.edges[i].id, correct: map.edges[i].correct});
    }
    msg.data.responses = responses;
    ws.send(JSON.stringify(msg));
    show_undo = true;
}

function learn() {
    var msg = {
        keyword: "LEARN-REQUEST",
        data: {}
    }
    ws.send(JSON.stringify(msg));
}

function done_learning(data, successful_days) {
    if (data.source != "") {
        if (successful_days < 6) document.getElementById(cont).innerHTML = "<p>Er zijn geen flashcards meer behorende tot de paragrafen die je gelezen hebt. Je bent daarmee klaar voor vandaag, en je hebt nog "+ (6 - successful_days).toString() +" dagen te gaan. Als je paragraaf " + data.source + " gelezen kun je verder met de volgende flashcards.</p><a href='#' onclick='confirm_source(\"" + data.source + "\")'> Verder
```

```
            </a>";
        else if (successful_days == 6) document.getElementById(cont).innerHTML =
            "<p>Er zijn geen flashcards meer behorende tot de paragrafen die je
            gelezen hebt. Je bent daarmee klaar voor vandaag, kom morgen terug
            voor de laatste kennistoets en de enquete. Als je paragraaf " + data.
            source + " gelezen kun je verder met de volgende flashcards.</p><a
            href='#' onclick='confirm_source(\"" + data.source + "\")'> Verder </a
            >";
        else document.getElementById(cont).innerHTTML = document.getElementById(
            cont).innerHTML = "<p>Er zijn geen flashcards meer behorende tot de
            paragrafen die je gelezen hebt. Je bent daarmee klaar voor vandaag.
            Als je paragraaf " + data.source + " gelezen kun je verder met de
            volgende flashcards.</p><a href='#' onclick='confirm_source(\"" + data
            .source + "\")'> Verder </a>";
    }
    else {
        if (successful_days < 6) document.getElementById(cont).innerHTML ="<p>Er
            zijn geen flashcards meer voor nu, en daarmee ben je klaar voor
            vandaag. Je hebt nog "+ (6 - successful_days).toString() +" dagen te
            gaan.</p>";
        else if (successful_days == 6) document.getElementById(cont).innerHTML ="<
            p>Er zijn geen flashcards meer voor nu, en daarmee ben je klaar voor
            vandaag. Kom morgen terug voor de laatste kennistoets en de enquete.</
            p>";
        else document.getElementById(cont).innerHTML ="<p>Er zijn geen flashcards
            meer voor nu, en daarmee ben je klaar voor vandaag.</p>";
    }
    document.getElementById("panel").innerHTML = "";
}

function prompt_source_request(data) {
    document.getElementById(cont).innerHTML = "Heb je paragraaf " + data.source +
        " al gelezen? Zo nee, lees deze dan nu.";
    document.getElementById("panel").innerHTML = "<a href='#' onclick='
        confirm_source(\"" + data.source + "\")'> Gelezen </a>";
}

function confirm_source(source_) {
    var msg = {keyword: "READ_SOURCE_RESPONSE", data: { source : source_ }};
    ws.send(JSON.stringify(msg));
}

function help() {
    document.getElementById("instructions").innerHTML = "";
    document.getElementById("panel").innerHTML = "";
    document.getElementById(cont).innerHTML = "<p>Dankjewel voor het meedoen aan
        het experiment. Hier kun je iedere dag met de flashcards oefenen om je zo
        goed voor te kunnen bereiden op de toets over Nederlandse literatuur uit
        de 17de eeuw.</p><p>Het flashcard systeem is het meest effectief als je
        iedere dag tijd eraan besteed. Bovendien krijg je de waardebon alleen als
        je iedere dag het systeem gebruikt voor 15 minuten, of totdat de
        flashcards voor die dag op zijn. Op het moment dat je op een bepaalde dag
        klaar bent krijg je vanzelf een popup die aangeeft dat je klaar bent voor
        vandaag.</p>";
}

function debriefing() {
    document.getElementById("instructions").innerHTML = "";
    document.getElementById("panel").innerHTML = "";
    document.getElementById(cont).innerHTML = "<p>Hartelijk bedankt voor het
        meedoen aan het onderzoek, en gefeliciteerd met de waardebon. Je zult deze
         binnenkort van je leraar ontvangen als je de toezeggingsverklaring hebt
```

```
        ingeleverd. Verder staat het je vrij om gebruik te blijven maken van het
        flashcard systeem, het is goed om de kennis die je geleerd hebt vers te
        houden tot de toets. De resultaten van dit onderzoek kun je op verzoek ter
         inzage bij mij aanvragen. Als je net je email adres hebt ingevuld krijg
        je binnenkort een mail om een datum in te plannen voor het interview.
        Verder wens ik je nog veel succes voor dit vak. Als je nog vragen hebt kun
         je me altijd nog een email sturen (mvdenk@gmail.com).</p><a href='#'
        onclick='acc_debriefing()'>Gelezen</a>";
}

function acc_debriefing() {
    ws.send(JSON.stringify({keyword: "DEBRIEFING-RESPONSE", data: {}}));
}

function logout() {
    logged_in = false;
    ws.close();
    location.reload();
}
```

Screenshots of the client

Learning process

Figure 27: The user interface when prompting the user whether he has read paragraph 13.1

Figure 28: The user interface when prompting a flashcard

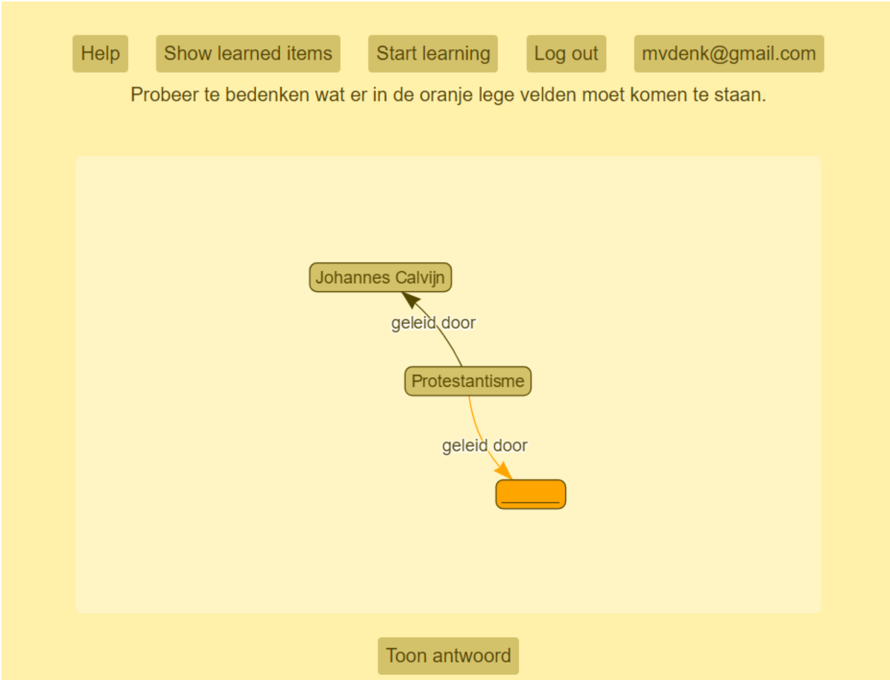


Figure 29: The user interface when prompting a flashmap

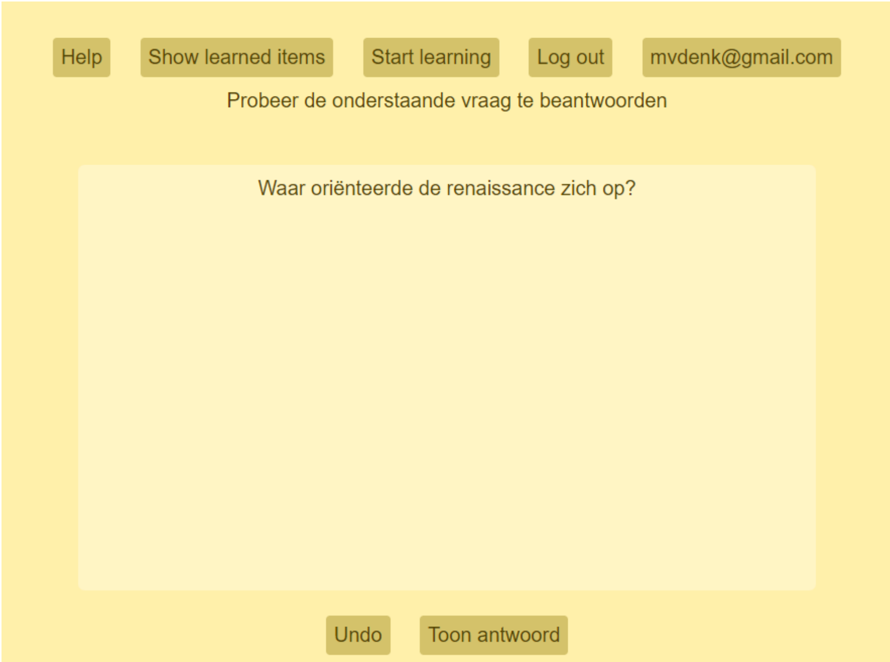


Figure 30: The user interface when prompting a flashcard with an undo option

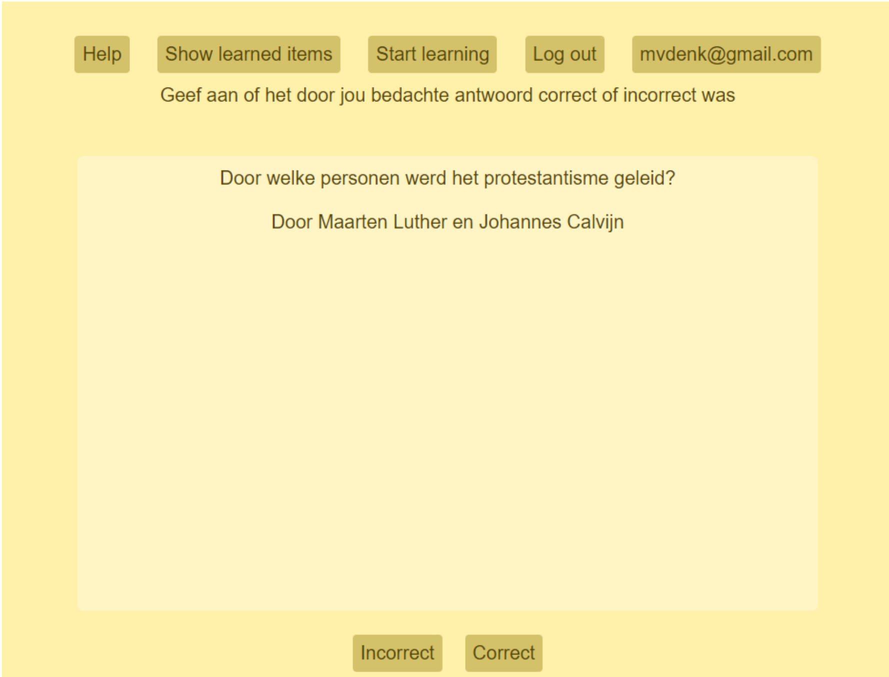


Figure 31: The user interface when showing the answer to a flashcard

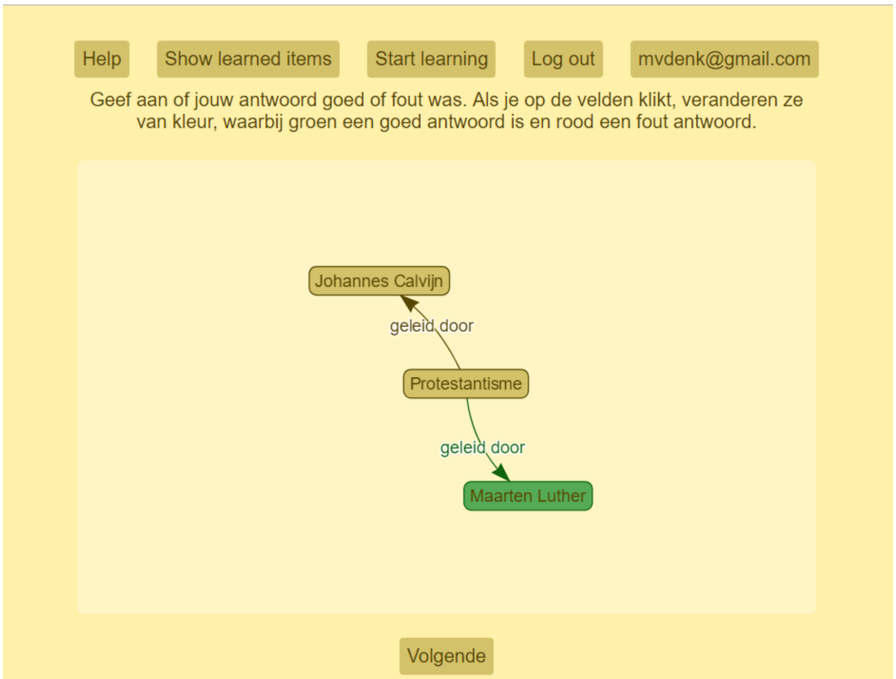


Figure 32: The user interface when showing the answer to a flashmap, here indicated as correct by the user

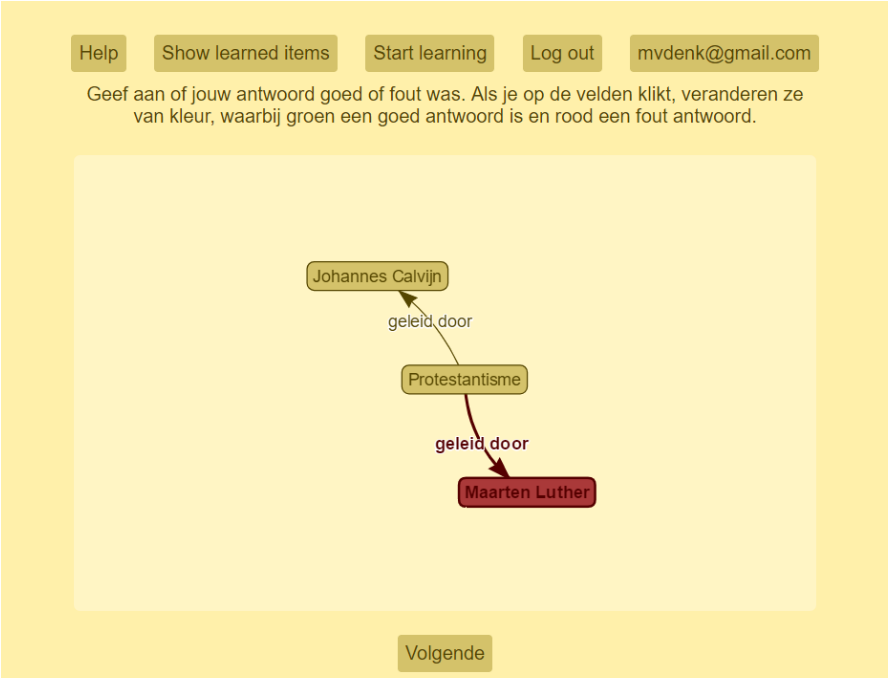


Figure 33: The user interface when showing the answer to a flashmap, here indicated as incorrect by the user

Figure 34: The user interface when showing that there are no new instances left to learn

a2d1a05

Other views

Figure 35: The login screen

Figure 36: The descriptives screen

Figure 37: The top of the test screen

Figure 38: The bottom of the test screen

Figure 39: The top of the questionnaire screen

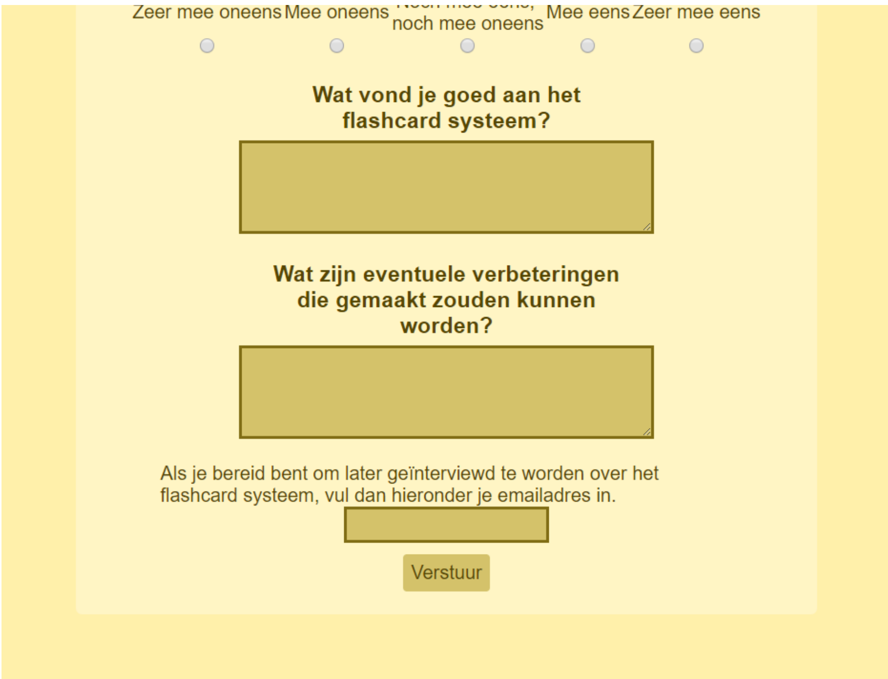


Figure 40: The bottom of the questionnaire screen

Figure 41: The debriefing screen

Figure 42: The help screen

Figure 43: The user interface when showing the learning progress to a flashcard user

Figure 44: The user interface when showing the learning progress to a flashcard user after reviewing some of the flashcards

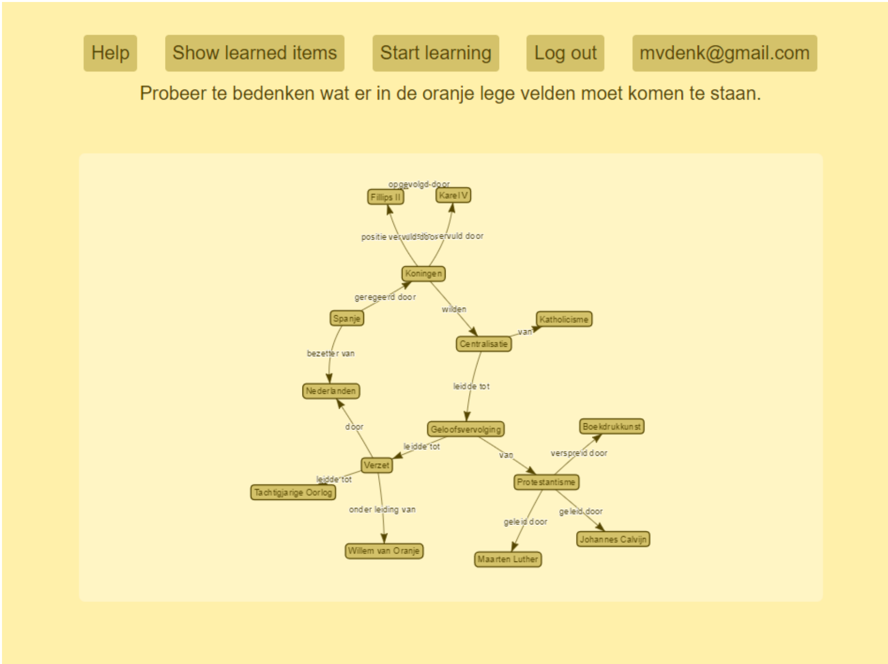


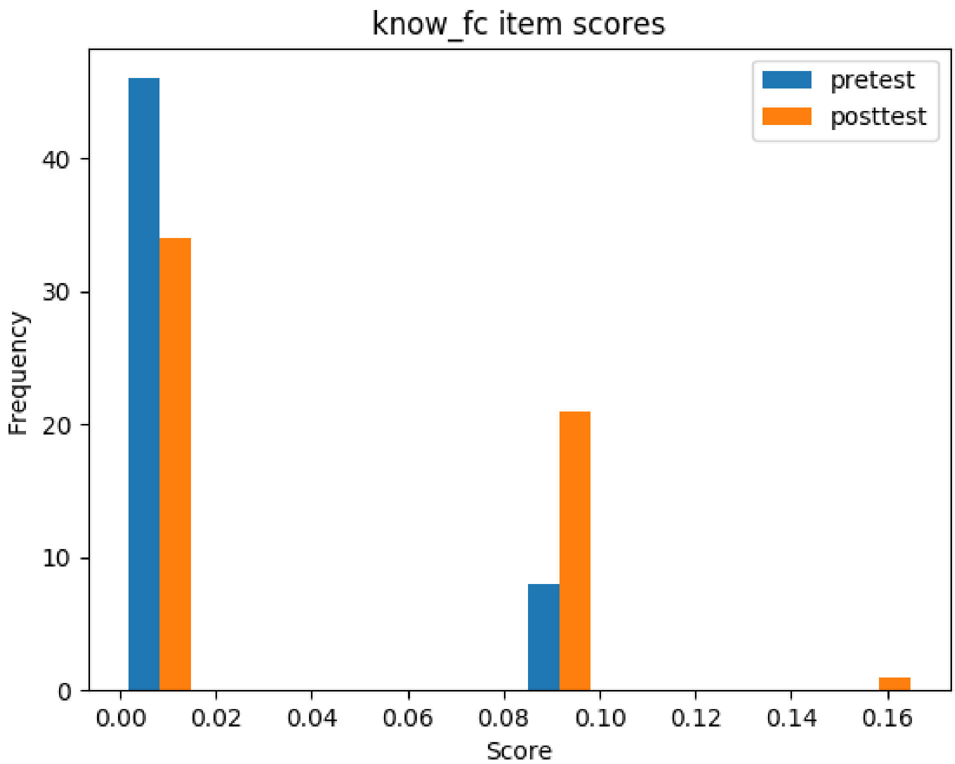
Figure 45: The user interface when showing the learning progress to a flashmap user

Pretest and posttest statistics

Descriptives of the knowledge questions

Table 4: Flashcard condition

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	24	0	6	1.29	4.13	1.34	0.40	8.732	0.0127	0.6958
ctt:pretest	12	0	3	0.67	1.15	1.16	-0.19	4.546	0.1030	0.4290
ctt:posttest	12	0	6	1.92	6.63	0.70	-1.29	3.371	0.1854	0.7261
ctt:abs_learn_gain	12	-3	6	1.25	8.39	0.47	-0.84	0.900	0.6378	0.4290
ctt:rel_learn_gain	12	0	0	0.04	0.00	0.43	-0.86	0.810	0.6671	0.4290
irt:total	24	-1	4	-0.03	3.05	1.05	0.04	5.537	0.0627	0.4556
irt:pretest	12	0	0	0.00	0.08	0.62	0.07	2.059	0.3573	0.0687
irt:posttest	12	-2	3	-0.01	2.70	0.61	0.63	3.146	0.2074	0.3769
irt:abs_learn_gain	12	-2	3	-0.01	2.87	0.91	0.61	4.553	0.1026	0.0687
irt:rel_learn_gain	12	0	0	0.02	0.00	0.90	0.59	4.487	0.1061	0.0687
fixed irt:total	24	-4	3	-0.83	4.14	0.58	-0.36	1.812	0.4042	0.5294
fixed irt:pretest	12	1	3	2.60	0.17	0.43	0.39	2.010	0.3661	0.1088
fixed irt:posttest	12	-2	3	-0.07	2.71	0.61	0.63	3.188	0.2031	0.3774
fixed irt:abs_learn_gain	12	-4	1	-2.67	2.91	1.01	0.64	5.199	0.0743	0.1088
fixed irt:rel_learn_gain	12	0	0	-0.03	0.00	1.01	0.62	5.132	0.0769	0.1088


know_fc item scores
pretest
posttest
Frequency
0
10
20
30
40
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Score

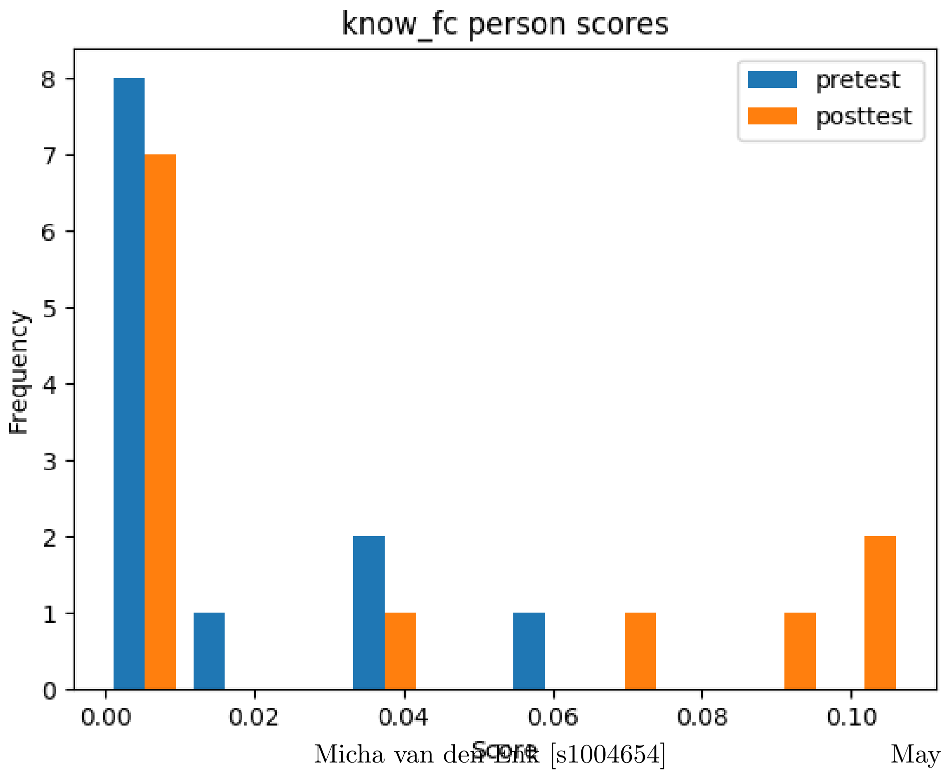
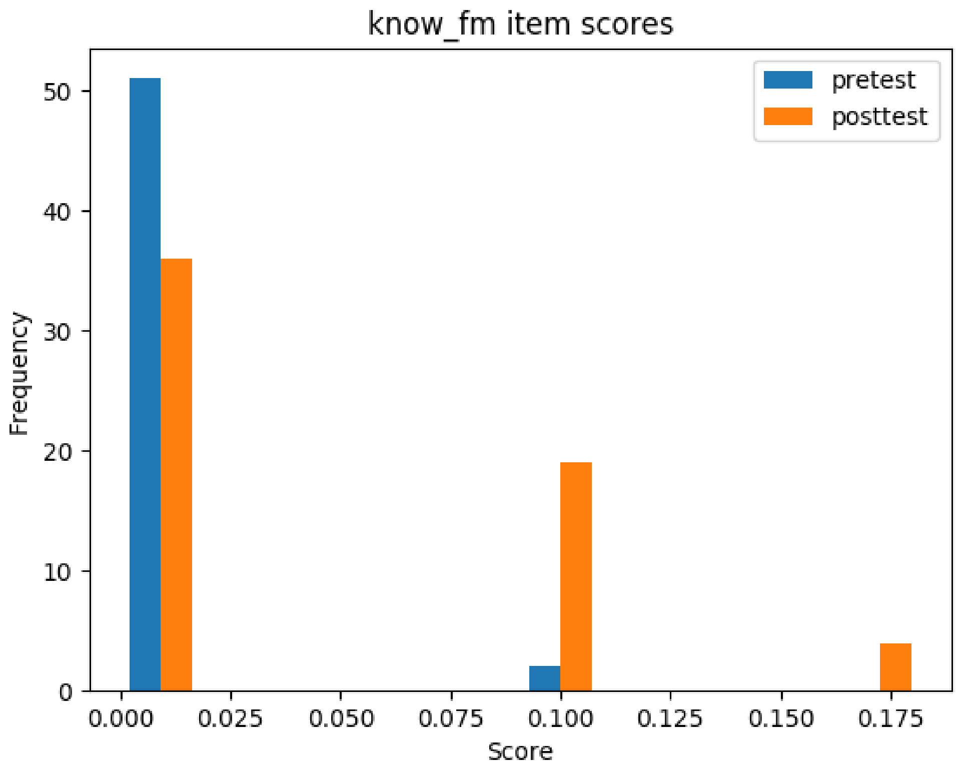

know_fc person scores
pretest
posttest
Frequency
0
1
2
3
4
5
6
7
8
0.00
0.02
0.04
0.06
0.08
0.10
Score

Table 5: Flashmap condition

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	22	0	7	1.32	4.89	1.48	0.77	10.348	0.0057	0.7424
ctt:pretest	11	0	1	0.18	0.16	1.65	0.72	9.711	0.0078	-0.1132
ctt:posttest	11	0	7	2.45	7.27	0.45	-1.31	2.304	0.3160	0.6841
ctt:abs_learn_gain	11	-1	7	2.27	7.42	0.45	-1.14	1.448	0.4848	-0.1132
ctt:rel_learn_gain	11	0	0	0.05	0.00	0.44	-1.15	1.490	0.4747	-0.1132
irt:total	22	-2	4	-0.03	3.02	0.62	0.46	3.124	0.2097	0.3942
irt:pretest	11	0	0	-0.00	0.00	1.65	0.72	9.711	0.0078	0.0000
irt:posttest	11	-1	1	-0.00	0.76	-0.00	2.50	6.534	0.0381	0.1362
irt:abs_learn_gain	11	-1	1	-0.00	0.76	-0.00	2.50	6.534	0.0381	0.0000
irt:rel_learn_gain	11	0	0	0.02	0.00	0.00	2.50	7.592	0.0225	0.0000
fixed irt:total	22	-4	3	-0.80	3.94	0.17	0.04	0.556	0.7575	0.4530
fixed irt:pretest	11	0	0	0.11	0.00	0.00	-3.00	1.057	0.5894	0.0000
fixed irt:posttest	11	2	4	3.27	0.15	-0.02	2.44	6.403	0.0407	0.1020
fixed irt:abs_learn_gain	11	2	4	3.17	0.15	-0.02	2.44	6.403	0.0407	0.0000
fixed irt:rel_learn_gain	11	0	0	0.07	0.00	-0.02	2.44	6.403	0.0407	0.0000


know_fm item scores
pretest
posttest
Frequency
Score
0
10
20
30
40
50
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

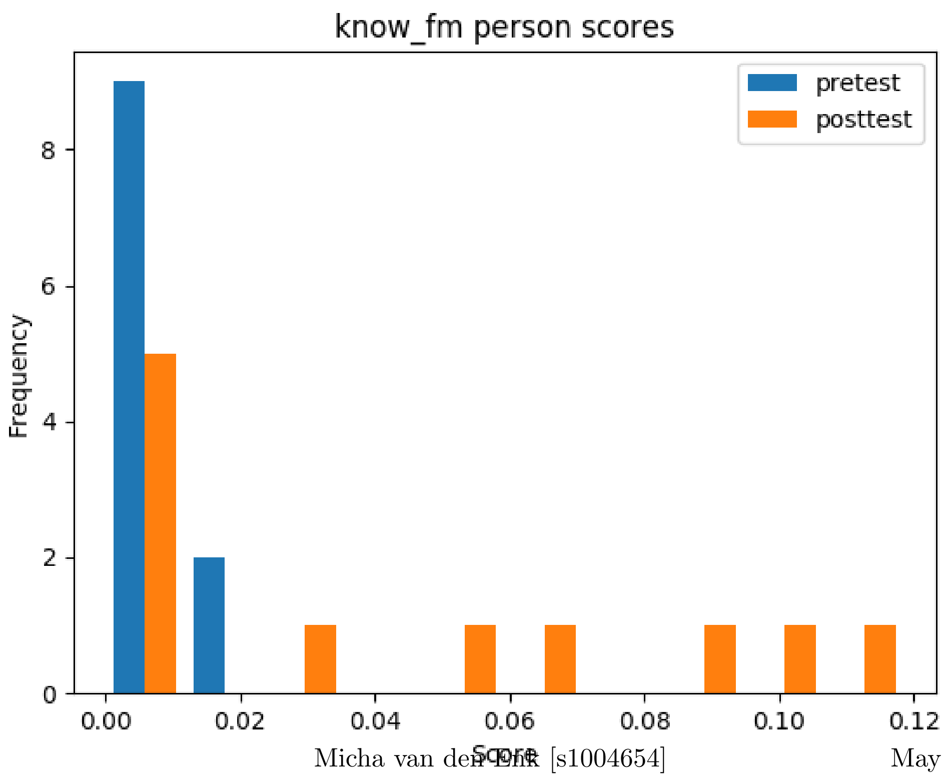
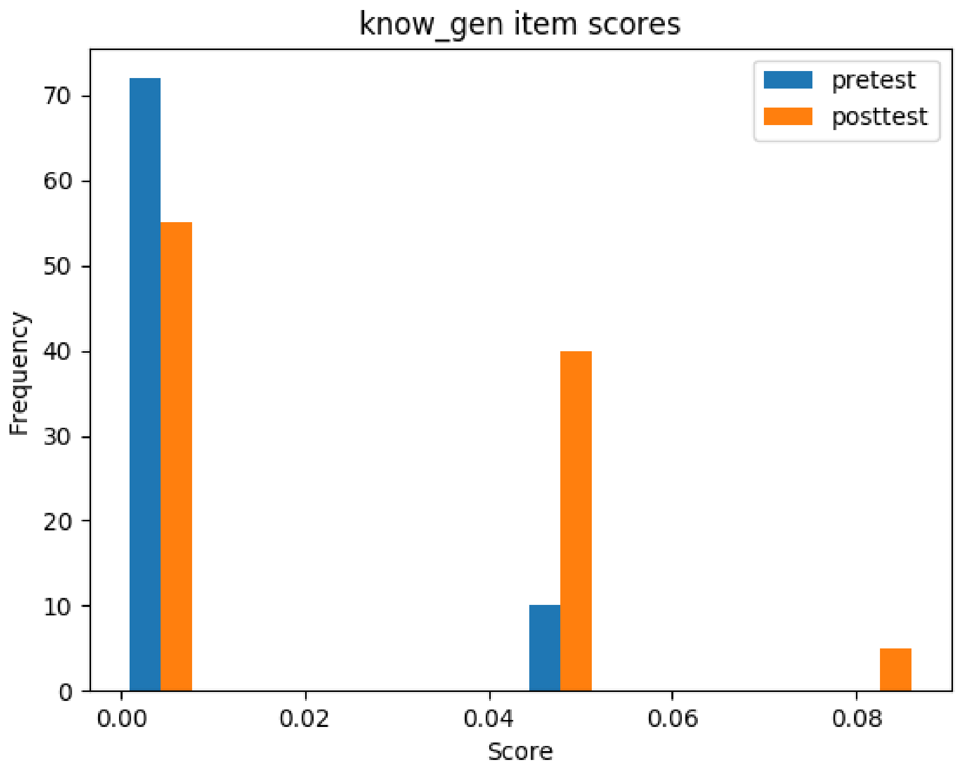
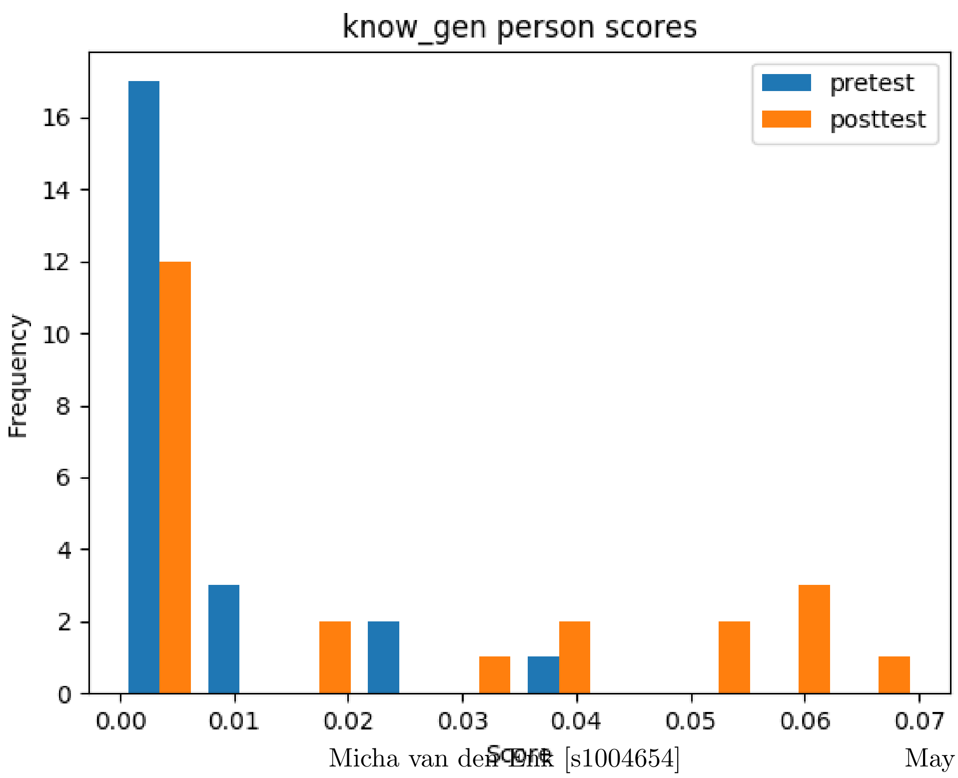

know_fm person scores
pretest
posttest
Frequency
Score
0
2
4
6
8
0.00
0.02
0.04
0.06
0.08
0.10
0.12

Table 6: Combined conditions

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	46	0	7	1.30	4.39	1.42	0.64	14.471	0.0007	0.7112
ctt:pretest	23	0	3	0.43	0.71	1.83	2.28	17.317	0.0002	0.3937
ctt:posttest	23	0	7	2.17	6.70	0.58	-1.30	6.839	0.0327	0.6851
ctt:abs_learn_gain	23	-3	7	1.74	7.84	0.40	-0.93	2.023	0.3637	0.3937
ctt:rel_learn_gain	23	0	0	0.03	0.00	0.39	-0.93	1.977	0.3722	0.3937
irt:total	46	-3	5	-0.10	4.92	0.98	-0.23	7.303	0.0259	0.5856
irt:pretest	23	-2	2	-0.00	1.22	0.97	2.19	9.614	0.0082	0.2141
irt:posttest	23	-3	3	-0.02	3.68	0.87	-0.19	3.757	0.1528	0.4740
irt:abs_learn_gain	23	-4	4	-0.02	5.31	0.42	-0.29	0.967	0.6166	0.2141
irt:rel_learn_gain	23	0	0	0.01	0.00	0.38	-0.27	0.833	0.6592	0.2141
fixed irt:total	46	-5	3	-1.85	5.68	0.80	-0.29	5.224	0.0734	0.6710
fixed irt:pretest	23	-2	2	-0.01	1.22	0.98	2.19	9.677	0.0079	0.2142
fixed irt:posttest	23	-4	3	-0.88	5.74	0.31	-0.53	0.564	0.7541	0.5859
fixed irt:abs_learn_gain	23	-7	4	-0.88	8.23	-0.21	0.11	0.742	0.6900	0.2142
fixed irt:rel_learn_gain	23	0	0	0.00	0.00	-0.26	0.19	1.015	0.6019	0.2142

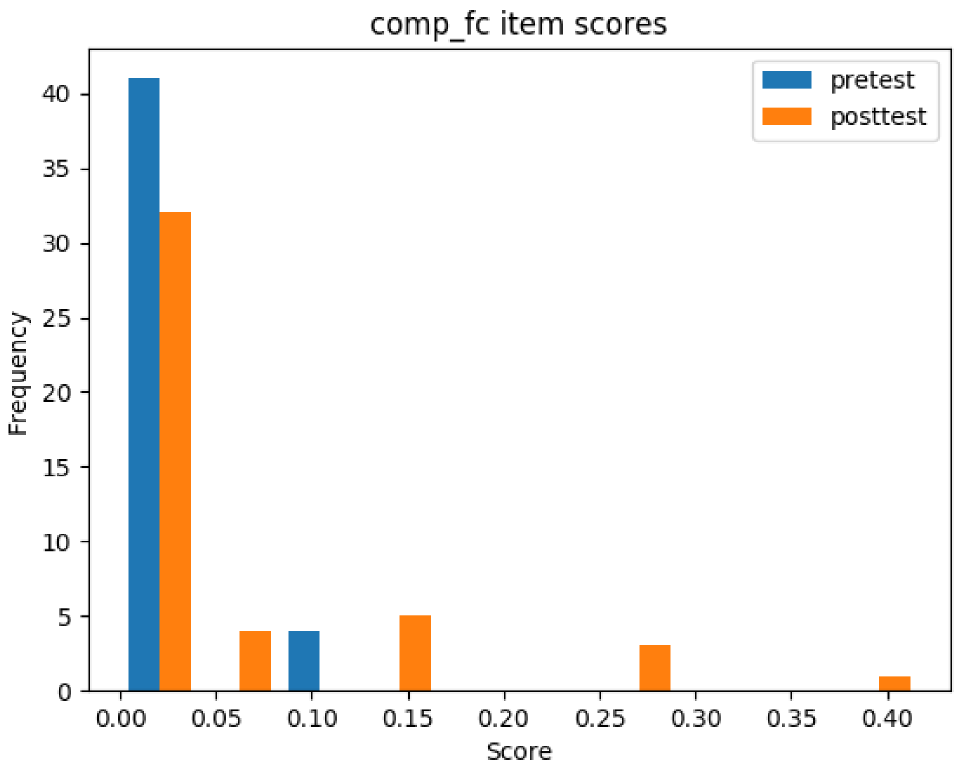

know_gen item scores
pretest
posttest
Frequency
Score
0
10
20
30
40
50
60
70
0.00
0.02
0.04
0.06
0.08


know_gen person scores
pretest
posttest
Frequency
Score
0
2
4
6
8
10
12
14
16
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07

Descriptives of the comprehension questions

Table 7: Flashcard condition

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	24	0	6	1.33	4.23	1.19	-0.05	6.646	0.0361	0.7215
ctt:pretest	12	0	4	0.33	1.33	3.02	7.09	33.648	0.0000	0.7670
ctt:posttest	12	0	6	2.33	5.33	0.41	-1.25	2.077	0.3540	0.6450
ctt:abs_learn_gain	12	0	6	2.00	5.45	0.72	-0.96	2.091	0.3516	0.6450
ctt:rel_learn_gain	12	0	0	0.07	0.00	0.72	-0.95	2.097	0.3504	0.6450
irt:total	24	-2	4	0.05	4.71	0.80	-0.83	4.030	0.1333	0.6583
irt:pretest	12	-1	4	-0.09	2.62	2.47	5.19	26.077	0.0000	0.3406
irt:posttest	12	-2	2	0.01	3.51	0.00	-1.31	1.869	0.3929	0.7510
irt:abs_learn_gain	12	-3	3	0.10	5.54	-0.07	-1.19	1.211	0.5459	0.3406
irt:rel_learn_gain	12	0	0	0.02	0.00	-0.15	-1.11	0.886	0.6420	0.3406
fixed irt:total	24	-3	3	-1.15	3.83	0.90	-0.52	4.058	0.1315	0.6673
fixed irt:pretest	12	0	5	0.42	2.58	2.72	6.04	29.551	0.0000	0.3207
fixed irt:posttest	12	-3	1	-0.87	3.16	0.03	-1.30	1.835	0.3994	0.7480
fixed irt:abs_learn_gain	12	-5	2	-1.28	5.01	-0.15	-1.04	0.652	0.7218	0.3207
fixed irt:rel_learn_gain	12	0	0	-0.01	0.00	-0.29	-0.81	0.411	0.8142	0.3207


comp_fc item scores
pretest
posttest
Frequency
Score
0
5
10
15
20
25
30
35
40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

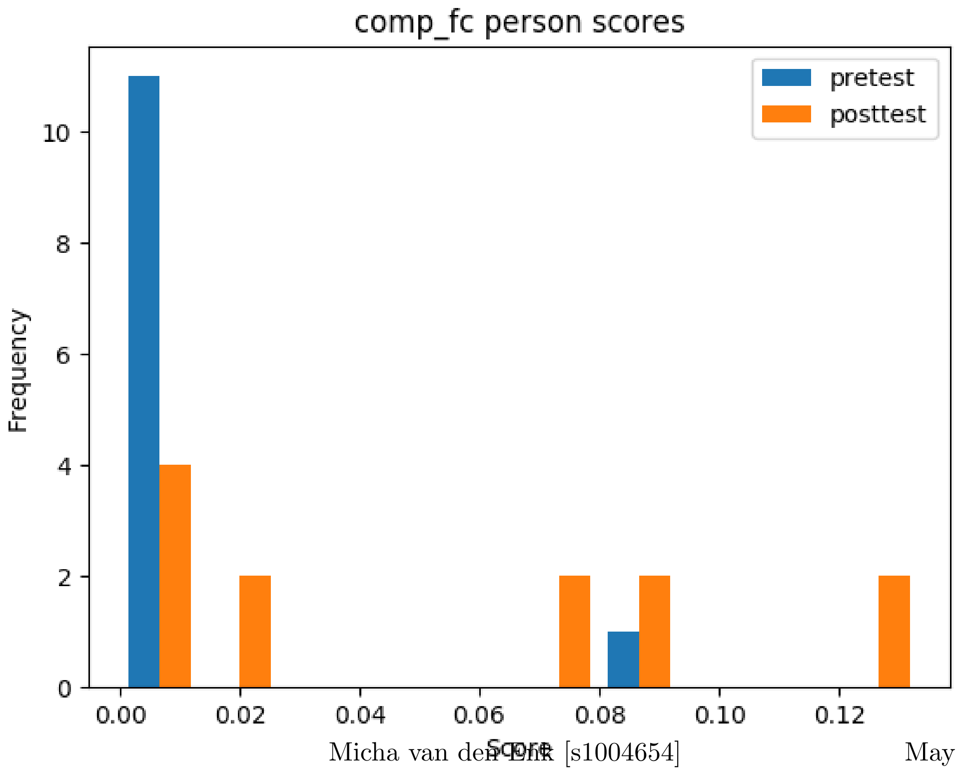
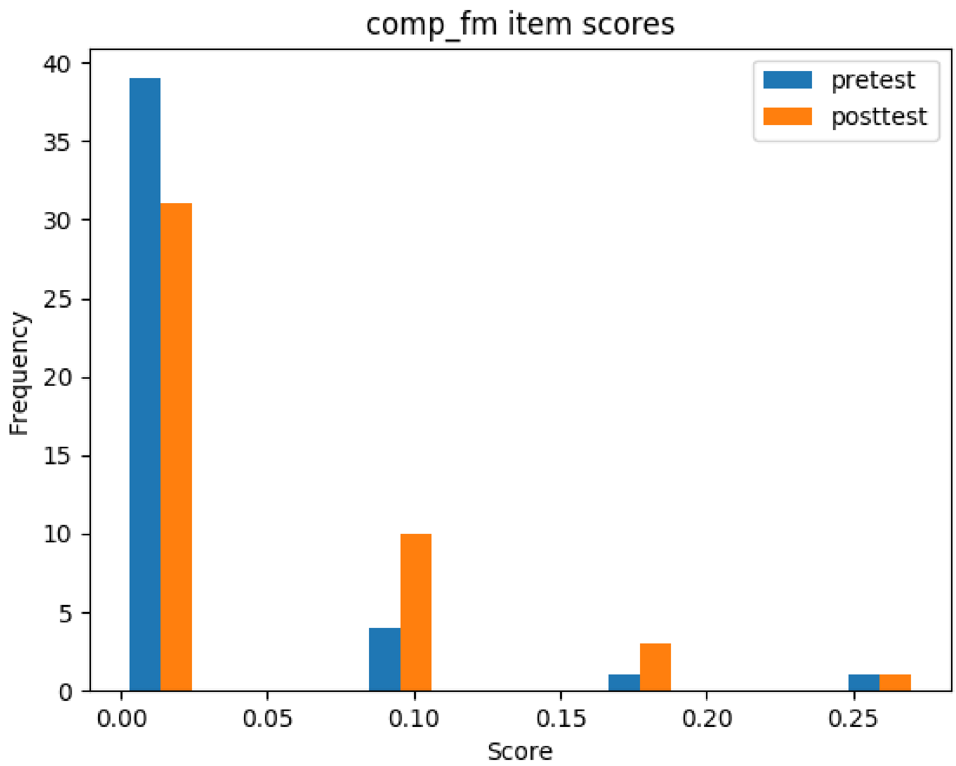

comp_fc person scores
pretest
posttest
Frequency
Score
0
2
4
6
8
10
0.00
0.02
0.04
0.06
0.08
0.10
0.12

Table 8: Flashmap condition

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	22	0	8	1.27	3.92	2.06	4.13	22.828	0.0000	0.7202
ctt:pretest	11	0	4	0.82	1.56	1.64	1.82	12.332	0.0021	0.5351
ctt:posttest	11	0	8	1.73	6.22	1.58	1.62	11.397	0.0034	0.7566
ctt:abs_learn_gain	11	-1	4	0.91	2.89	1.04	-0.35	3.526	0.1715	0.5351
ctt:rel_learn_gain	11	0	0	0.04	0.00	1.09	-0.23	3.961	0.1380	0.5351
irt:total	22	-1	3	0.01	2.83	0.65	-1.02	3.743	0.1539	0.6260
irt:pretest	11	-1	3	-0.00	2.98	0.91	-0.34	2.786	0.2483	0.5317
irt:posttest	11	-2	2	0.01	3.41	0.19	-1.62	4.801	0.0907	0.6901
irt:abs_learn_gain	11	-1	2	0.01	1.71	1.00	-0.12	3.564	0.1683	0.5317
irt:rel_learn_gain	11	0	0	0.02	0.00	0.99	-0.11	3.521	0.1720	0.5317
fixed irt:total	22	-1	3	0.05	2.92	0.66	-1.01	3.727	0.1551	0.6277
fixed irt:pretest	11	0	4	1.54	2.10	0.93	-0.32	2.893	0.2354	0.4888
fixed irt:posttest	11	-1	3	0.57	3.81	0.15	-1.64	5.133	0.0768	0.6957
fixed irt:abs_learn_gain	11	-2	1	-0.97	1.88	1.08	0.01	4.284	0.1174	0.4888
fixed irt:rel_learn_gain	11	0	0	0.00	0.00	1.08	0.01	4.277	0.1178	0.4888


comp_fm item scores
Frequency
Score
pretest
posttest
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10
15
20
25
30
35
40
0.00
0.05
0.10
0.15
0.20
0.25

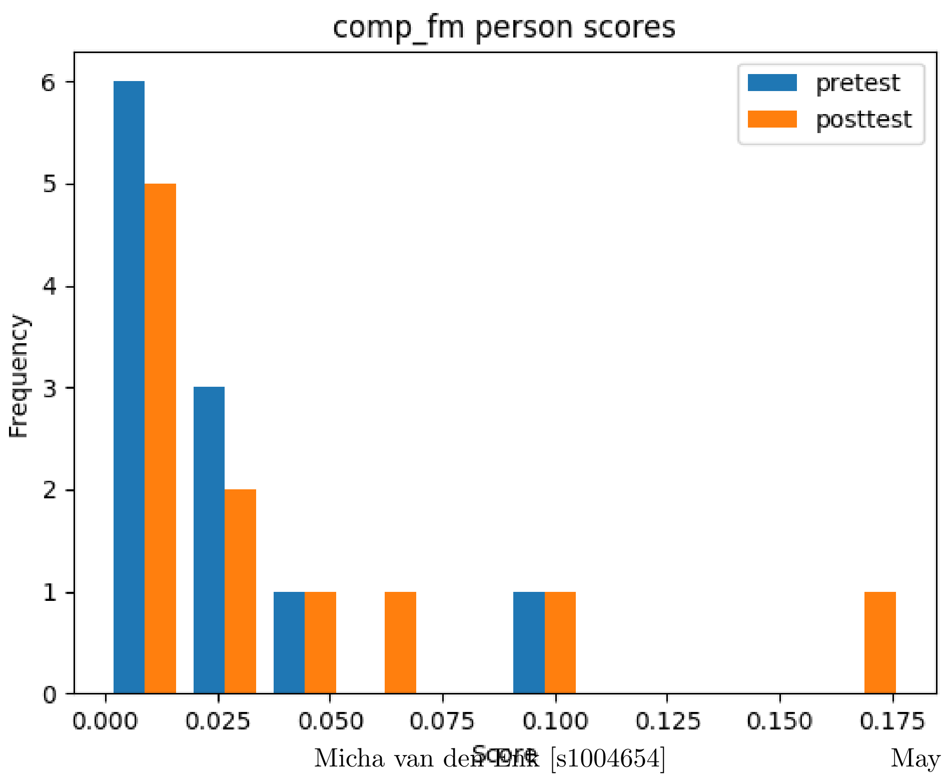
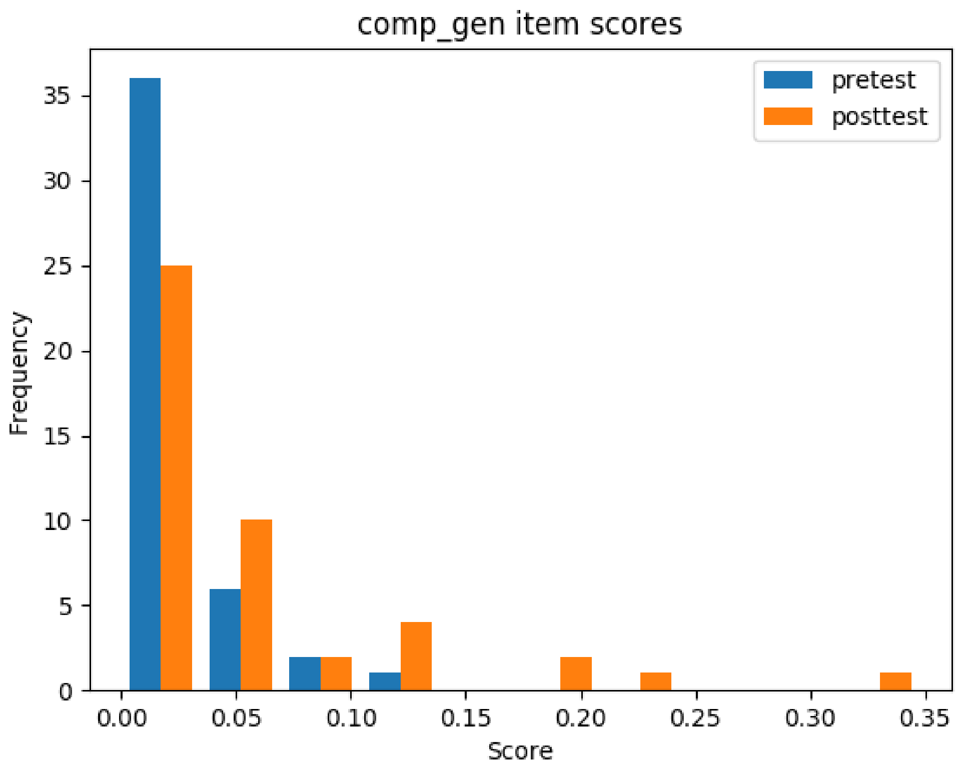
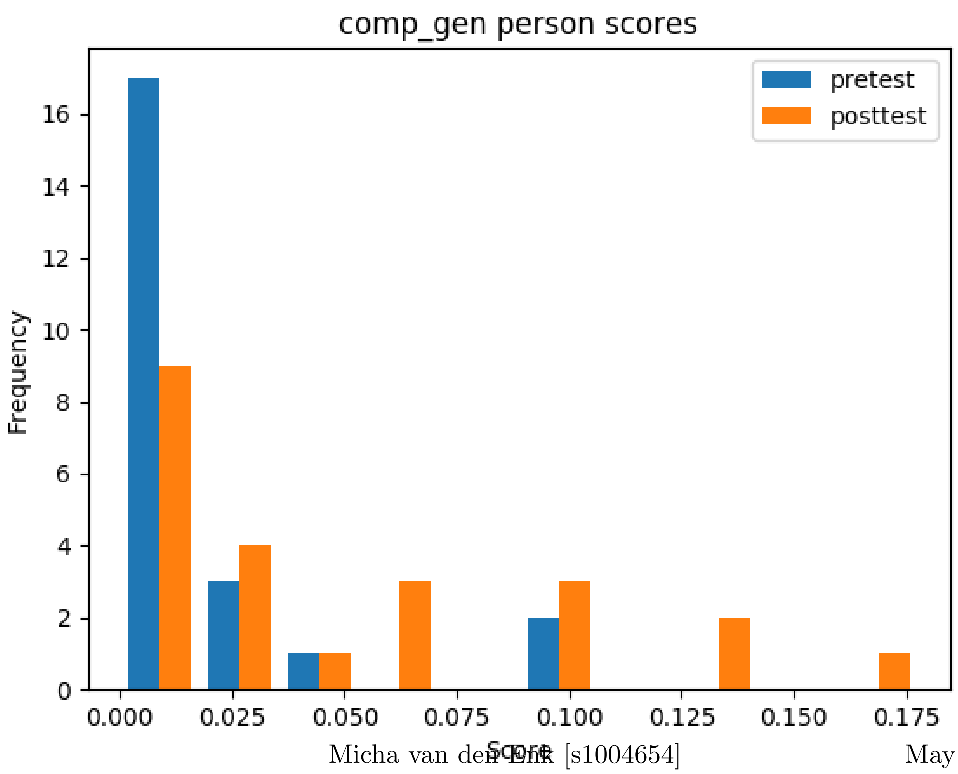

comp_fm person scores
Frequency
Score
pretest
posttest
0
1
2
3
4
5
6
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

Table 9: Combined conditions

	N	min	max	mean	var	skew	kurt	norm-t	norm-p	α
ctt:total	46	0	8	1.30	3.99	1.58	1.77	19.890	0.0000	0.7140
ctt:pretest	23	0	4	0.57	1.44	2.19	3.53	23.159	0.0000	0.6350
ctt:posttest	23	0	8	2.04	5.59	0.98	-0.02	4.808	0.0903	0.6951
ctt:abs_learn_gain	23	-1	6	1.48	4.35	0.97	-0.34	4.419	0.1097	0.6350
ctt:rel_learn_gain	23	0	0	0.05	0.00	0.95	-0.42	4.277	0.1178	0.6350
irt:total	46	-1	3	0.00	2.33	0.81	-0.90	8.324	0.0156	0.6015
irt:pretest	23	-1	4	0.01	2.56	1.65	1.53	13.943	0.0009	0.4629
irt:posttest	23	-1	2	0.00	2.04	0.19	-1.52	11.285	0.0035	0.6781
irt:abs_learn_gain	23	-3	3	-0.01	2.86	0.32	-0.85	1.311	0.5192	0.4629
irt:rel_learn_gain	23	0	0	0.02	0.00	0.24	-0.77	0.786	0.6749	0.4629
fixed irt:total	46	-2	2	-0.62	2.30	0.82	-0.86	8.005	0.0183	0.6058
fixed irt:pretest	23	-1	4	0.04	2.52	1.66	1.54	13.979	0.0009	0.4618
fixed irt:posttest	23	-1	2	-0.23	1.97	0.17	-1.56	12.676	0.0018	0.6732
fixed irt:abs_learn_gain	23	-3	2	-0.26	2.85	0.27	-0.87	1.246	0.5362	0.4618
fixed irt:rel_learn_gain	23	0	0	0.02	0.00	0.18	-0.76	0.640	0.7262	0.4618


comp_gen item scores
pretest
posttest
Frequency
Score
0
5
10
15
20
25
30
35
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35


comp_gen person scores
pretest
posttest
Frequency
Score
0
2
4
6
8
10
12
14
16
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

Comparisons of the knowledge questions

Pre- and posttest comparisons

Table 10: Flashcard condition

	MW k	MW p	t-test k	t-test p
ctt	-1.552	0.1348	-1.552	0.1418
irt	0.016	0.9872	0.016	0.9873
fixed irt	5.454	0.0000	5.454	0.0001

Table 11: Flashmap condition

	MW k	MW p	t-test k	t-test p
ctt	-2.764	0.0120	-2.764	0.0192
irt	-0.000	1.0000	-0.000	1.0000
fixed irt	-27.206	0.0000	-27.206	0.0000

Table 12: Combined conditions

	MW k	MW p	t-test k	t-test p
ctt	-3.065	0.0037	-3.065	0.0049
irt	0.051	0.9597	0.051	0.9598
fixed irt	1.591	0.1187	1.591	0.1217

Between conditions

Table 13: Classical test theory

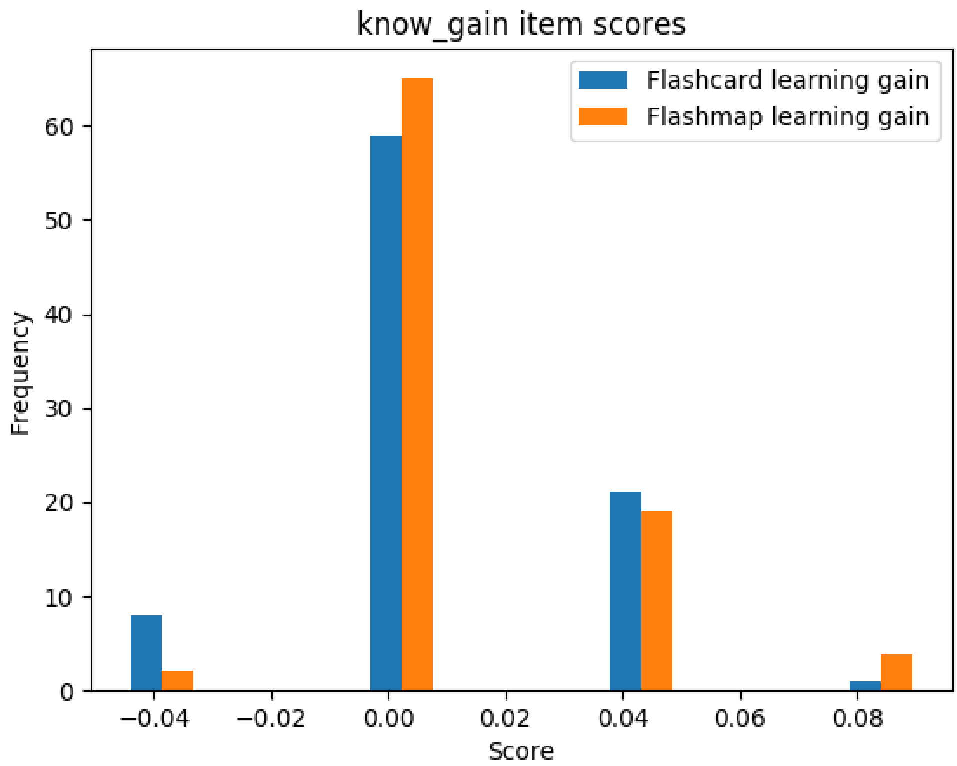
	MW k	MW p	t-test k	t-test p
total	-0.042	0.9664	-0.042	0.9665
pretest	1.407	0.1739	1.456	0.1669
posttest	-0.489	0.6297	-0.488	0.6305
abs_learn_gain	-0.870	0.3940	-0.873	0.3927
rel_learn_gain	-0.747	0.4635	-0.751	0.4611

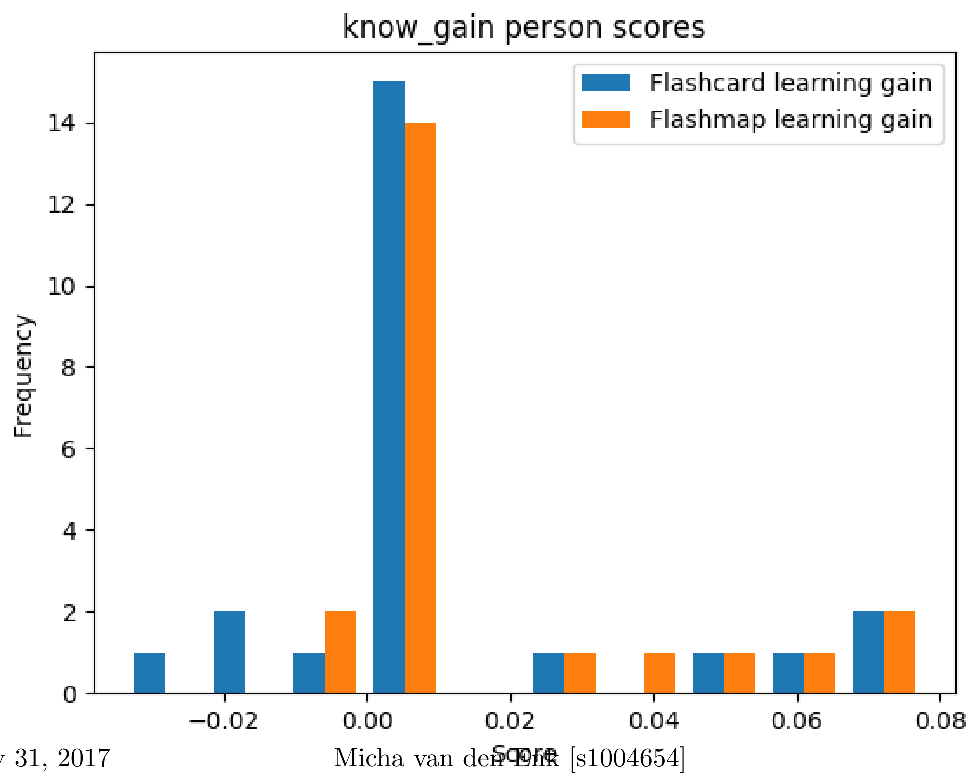
Table 14: Item response theory

	MW k	MW p	t-test k	t-test p
total	-0.001	0.9989	-0.001	0.9989
pretest	0.000	1.0000	0.000	1.0000
posttest	-0.014	0.9889	-0.014	0.9887
abs_learn_gain	-0.014	0.9892	-0.014	0.9889
rel_learn_gain	0.072	0.9436	0.074	0.9423

Table 15: Item response theory with fixed item difficulties

	MW k	MW p	t-test k	t-test p
total	-0.050	0.9602	-0.050	0.9602
pretest	20.261	0.0000	21.204	0.0000
posttest	-6.549	0.0000	-6.821	0.0000
abs_learn_gain	-11.067	0.0000	-11.531	0.0000
rel_learn_gain	-10.401	0.0000	-10.845	0.0000


know_gain item scores
Flashcard learning gain
Flashmap learning gain
Frequency
Score
0
10
20
30
40
50
60
−0.04
−0.02
0.00
0.02
0.04
0.06
0.08


know_gain person scores
Flashcard learning gain
Flashmap learning gain
Frequency
Score
0
2
4
6
8
10
12
14
−0.02
0.00
0.02
0.04
0.06
0.08

Comparisons of the comprehension questions

Table 16: Flashcard condition

	MW k	MW p	t-test k	t-test p
ctt	-2.683	0.0136	-2.683	0.0162
irt	-0.146	0.8852	-0.146	0.8852
fixed irt	1.856	0.0768	1.856	0.0770

Table 17: Flashmap condition

	MW k	MW p	t-test k	t-test p
ctt	-1.081	0.2926	-1.081	0.2971
irt	-0.018	0.9854	-0.018	0.9854
fixed irt	1.318	0.2024	1.318	0.2036

Table 18: Combined conditions

	MW k	MW p	t-test k	t-test p
ctt	-2.674	0.0105	-2.674	0.0116
irt	0.023	0.9818	0.023	0.9818
fixed irt	0.595	0.5549	0.595	0.5549

Between conditions

Table 19: Classical test theory

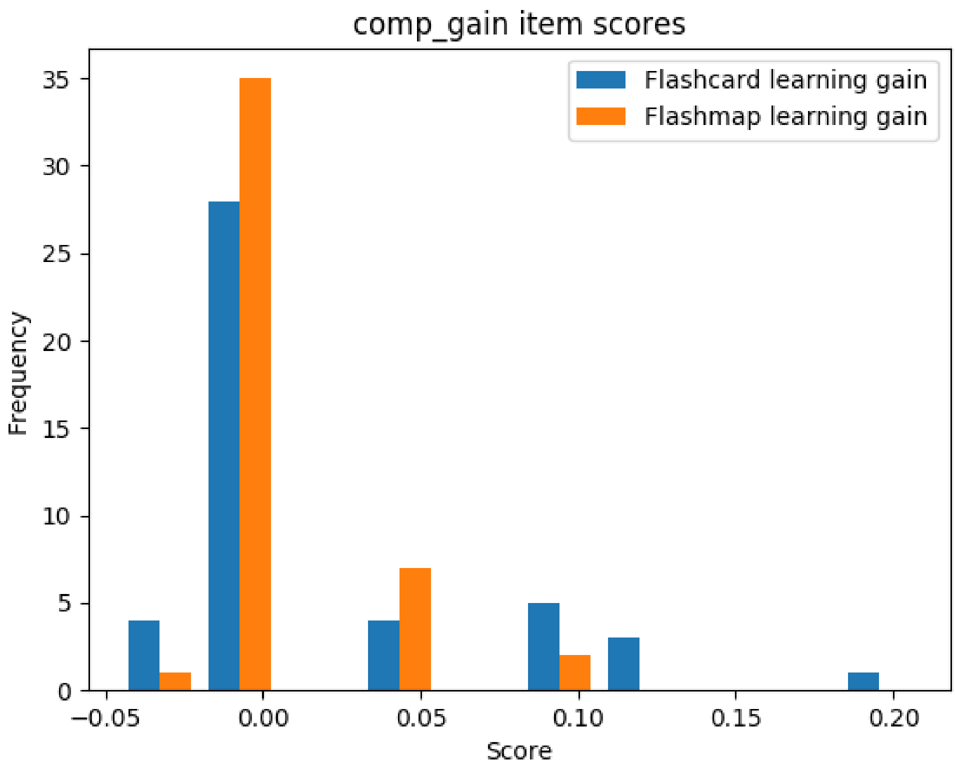
	MW k	MW p	t-test k	t-test p
total	0.102	0.9195	0.102	0.9194
pretest	-0.967	0.3446	-0.963	0.3466
posttest	0.605	0.5515	0.603	0.5531
abs_learn_gain	1.270	0.2179	1.288	0.2124
rel_learn_gain	1.197	0.2448	1.211	0.2399

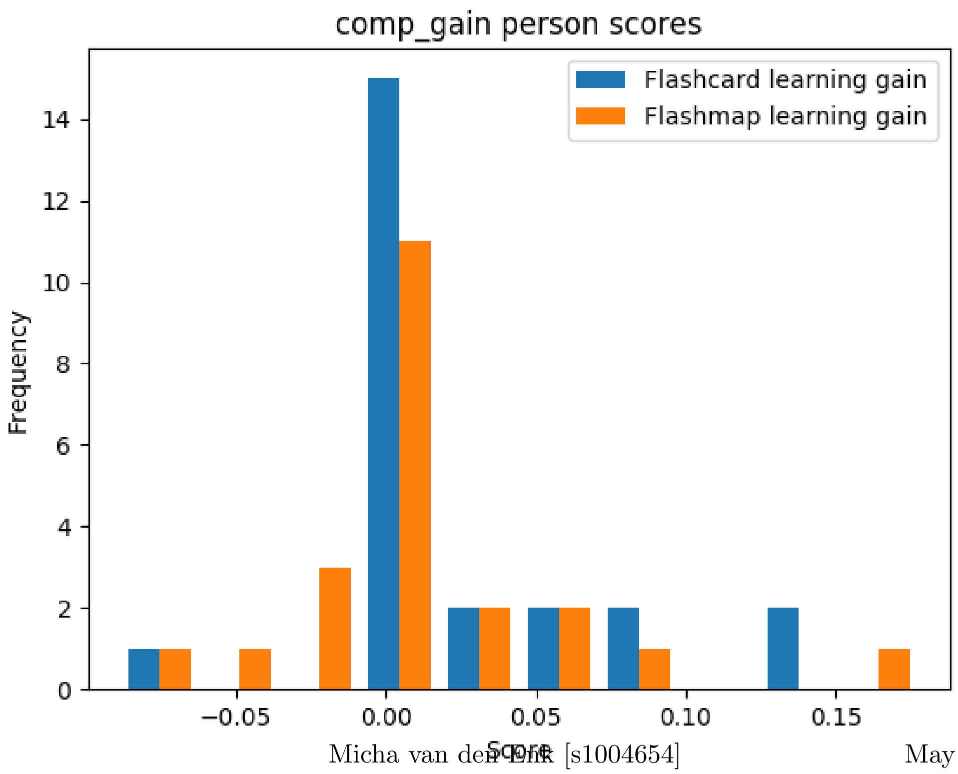
Table 20: Item response theory

	MW k	MW p	t-test k	t-test p
total	0.071	0.9436	0.072	0.9430
pretest	-0.132	0.8961	-0.132	0.8965
posttest	-0.002	0.9982	-0.002	0.9982
abs_learn_gain	0.112	0.9116	0.115	0.9097
rel_learn_gain	0.064	0.9496	0.066	0.9484

Table 21: Item response theory with fixed item difficulties

	MW k	MW p	t-test k	t-test p
total	-2.188	0.0340	-2.202	0.0330
pretest	-1.748	0.0950	-1.756	0.0936
posttest	-1.849	0.0785	-1.842	0.0802
abs_learn_gain	-0.407	0.6882	-0.415	0.6826
rel_learn_gain	-0.455	0.6537	-0.465	0.6476


comp_gain item scores
Flashcard learning gain
Flashmap learning gain
Frequency
Score
0
5
10
15
20
25
30
35
−0.05
0.00
0.05
0.10
0.15
0.20

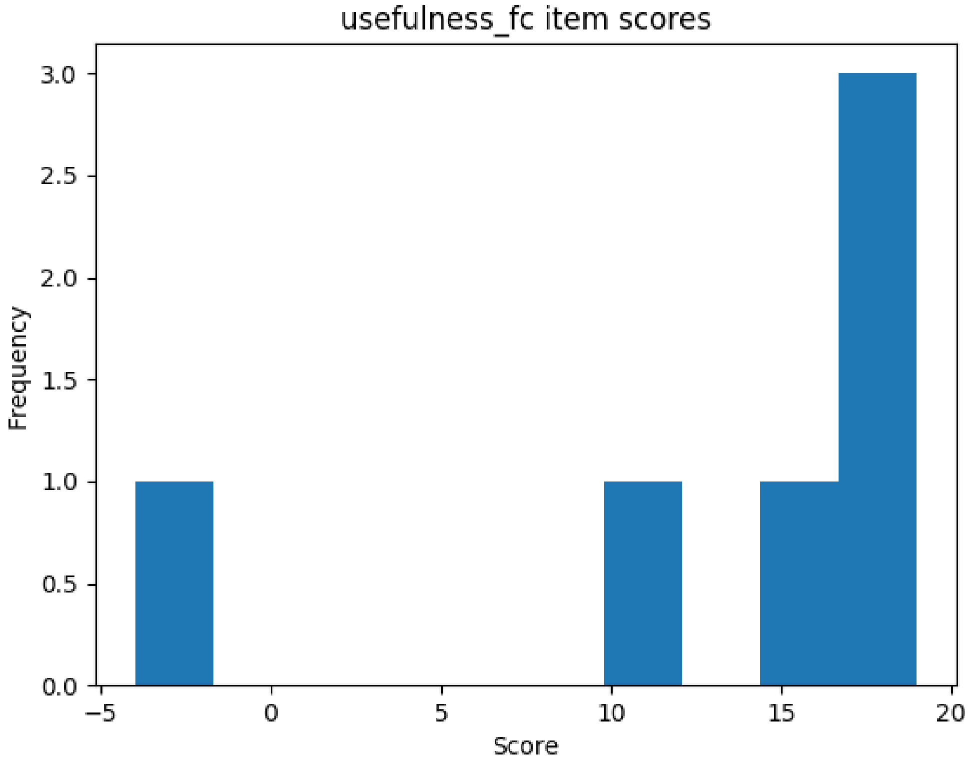

comp_gain person scores
Flashcard learning gain
Flashmap learning gain
Frequency
Score
0
2
4
6
8
10
12
14
−0.05
0.00
0.05
0.10
0.15

Questionnaire statistics

Descriptives of Perceived Usefulness questions

Table 22: Flashcard condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	12	-4	14	6.50	27.36	-0.57	-0.52	1.144	0.5643	0.6432
irt	12	-5	1	-0.16	4.40	-1.89	3.15	17.284	0.0002	0.6263


usefulness_fc item scores
Frequency
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−5
0
5
10
15
20

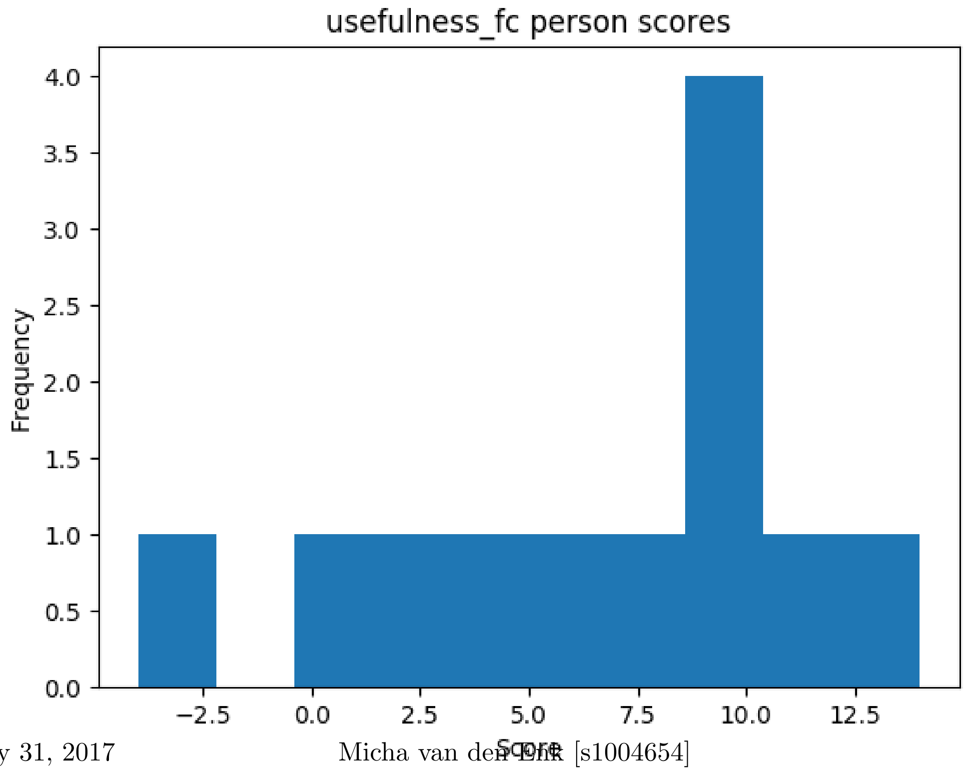
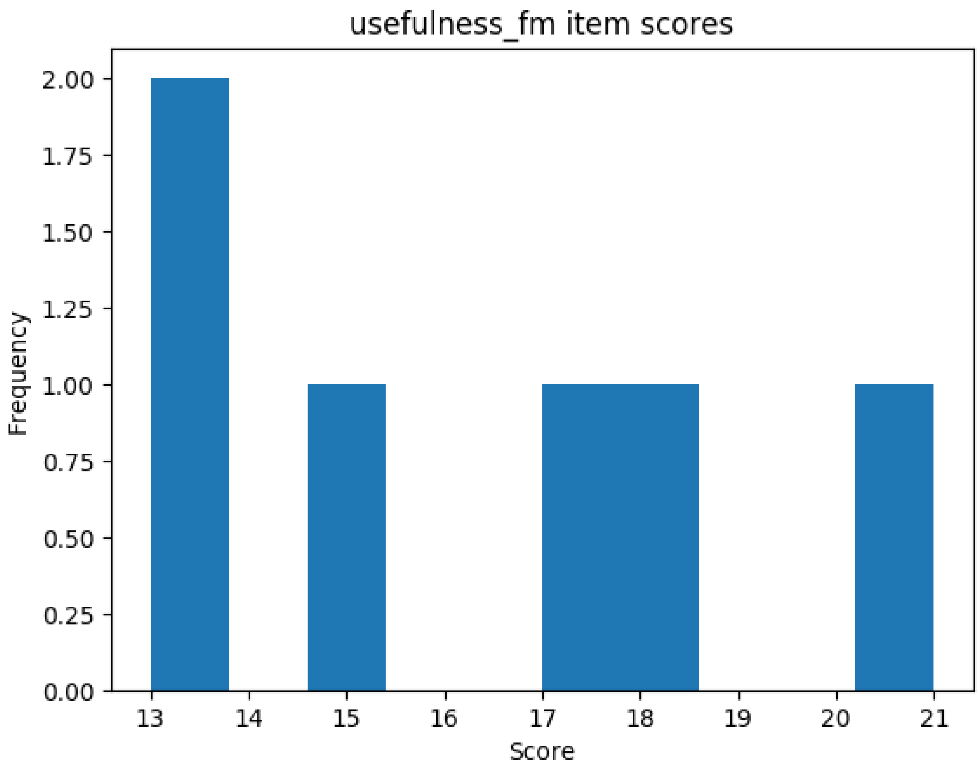

usefulness_fc person scores
Frequency
Score
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−2.5
0.0
2.5
5.0
7.5
10.0
12.5

Table 23: Flashmap condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	11	0	13	8.82	15.16	-1.05	0.32	4.698	0.0955	0.6777
irt	11	-3	1	-0.15	1.89	-1.41	1.44	9.670	0.0079	0.5298


usefulness_fm item scores
Frequency
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
13
14
15
16
17
18
19
20
21
Score

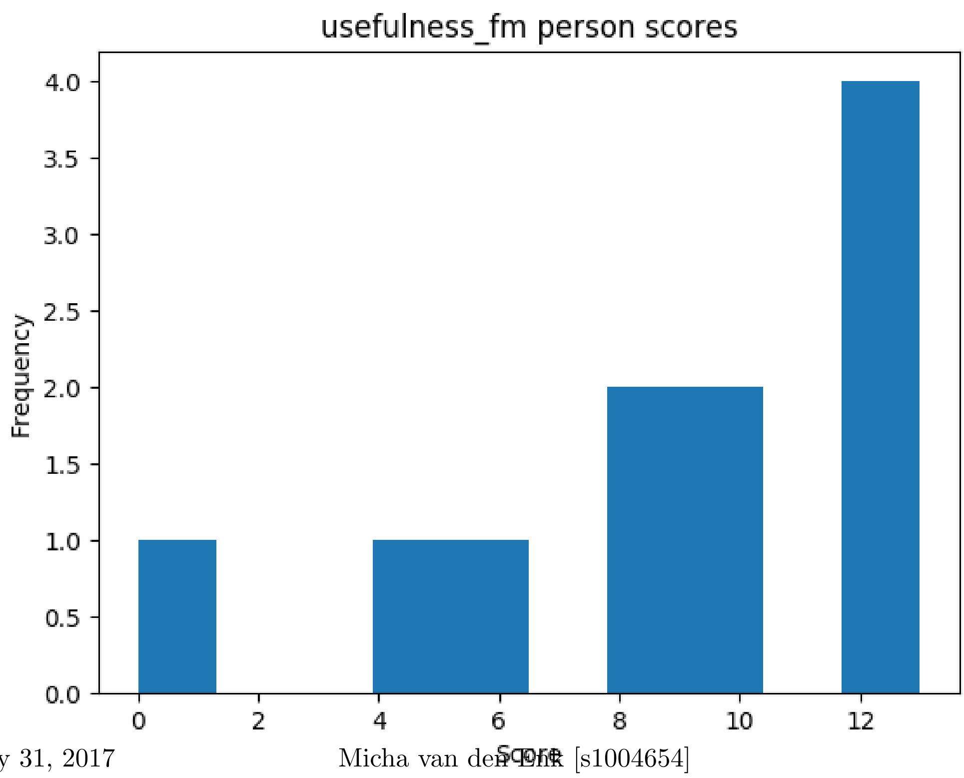
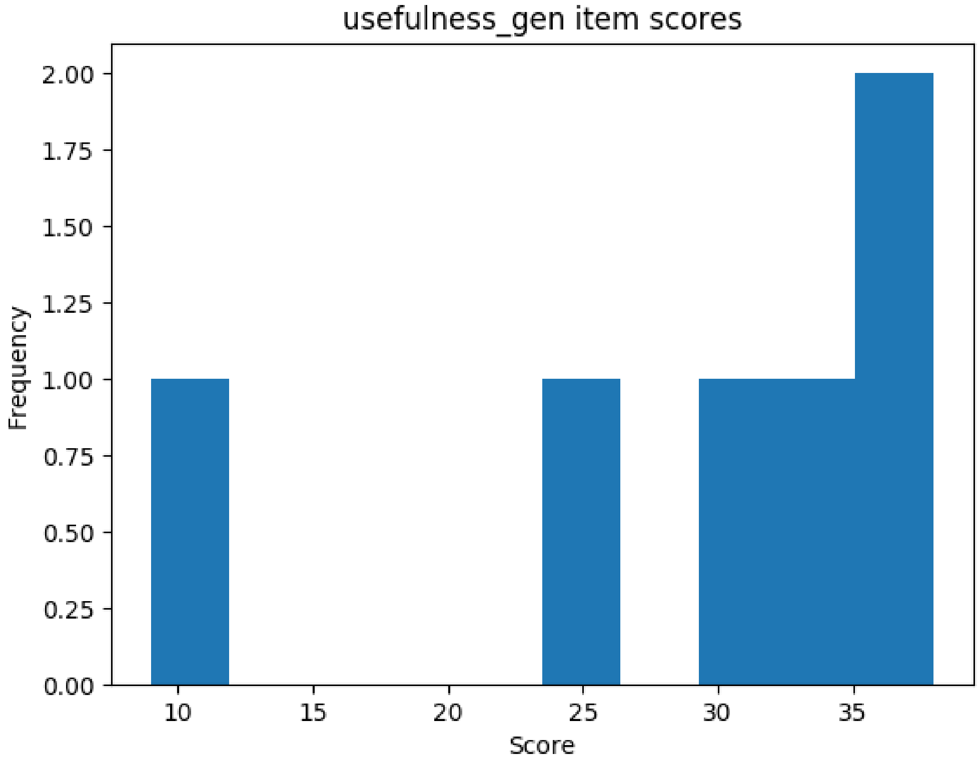
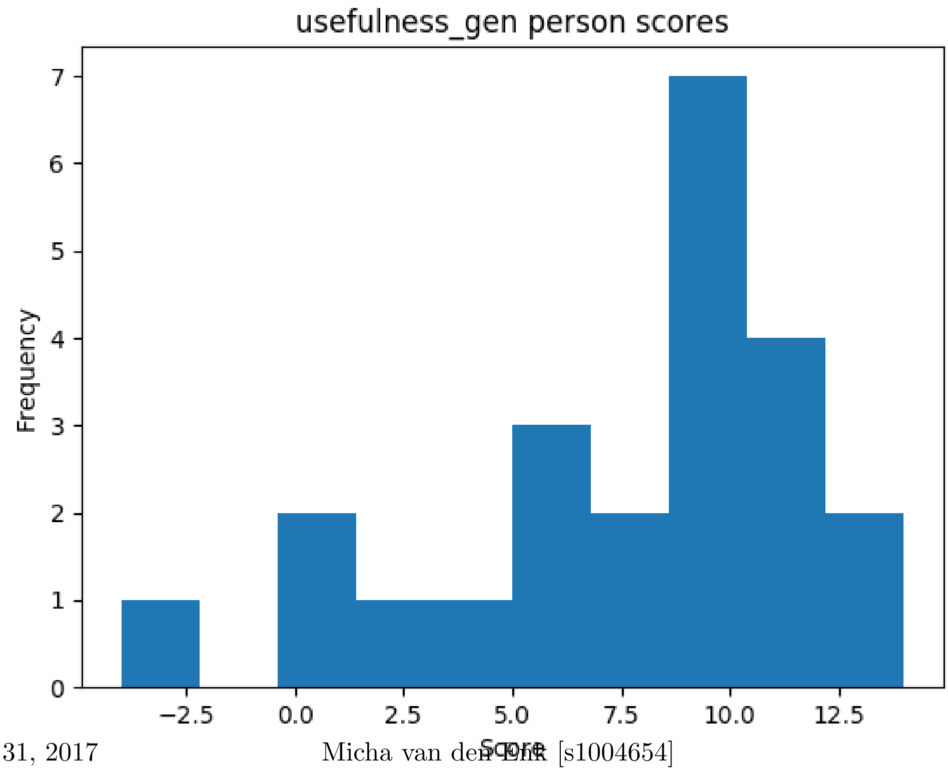

usefulness_fm person scores
Frequency
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
Score

Table 24: Combined conditions

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	23	-4	14	7.61	21.98	-0.86	-0.02	3.864	0.1448	0.6509
irt	23	-3	2	0.49	1.82	-0.73	0.55	4.058	0.1315	0.4619

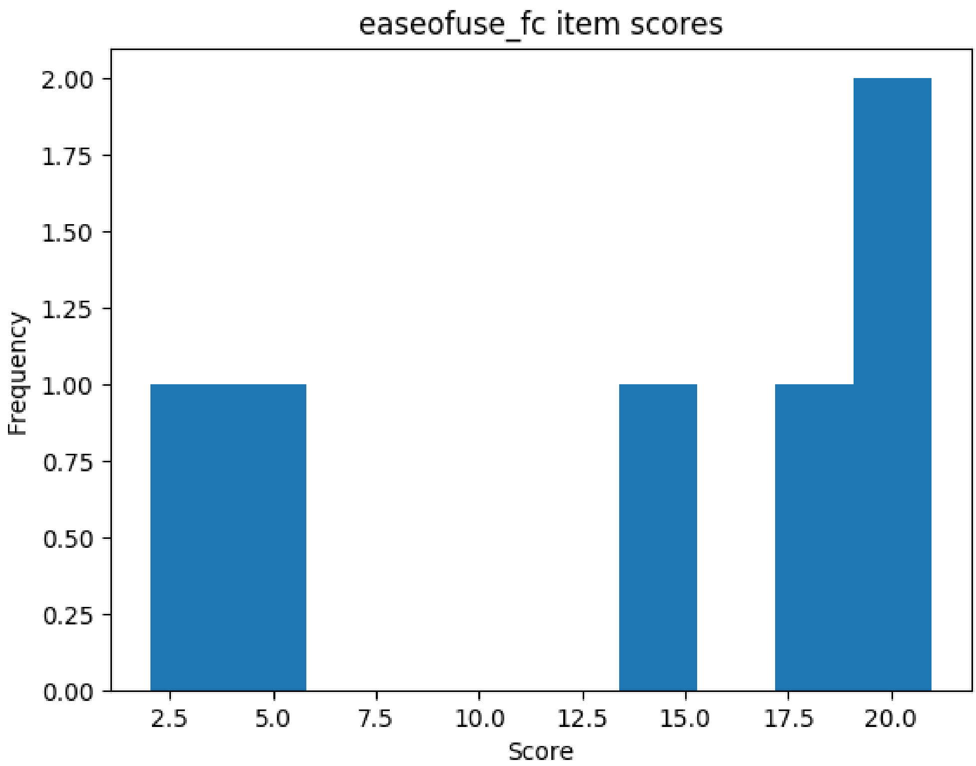

usefulness_gen item scores
Frequency
Score
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
10
15
20
25
30
35


usefulness_gen person scores
Frequency
Score
7
6
5
4
3
2
1
0
−2.5
0.0
2.5
5.0
7.5
10.0
12.5

Descriptives of Perceived Ease of Use questions

Table 25: Flashcard condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	12	-4	17	6.58	38.08	-0.26	-0.62	0.232	0.8904	0.8794
irt	12	0	4	0.91	1.87	1.08	0.52	5.358	0.0686	0.2295


easeofuse_fc item scores
Frequency
Score
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

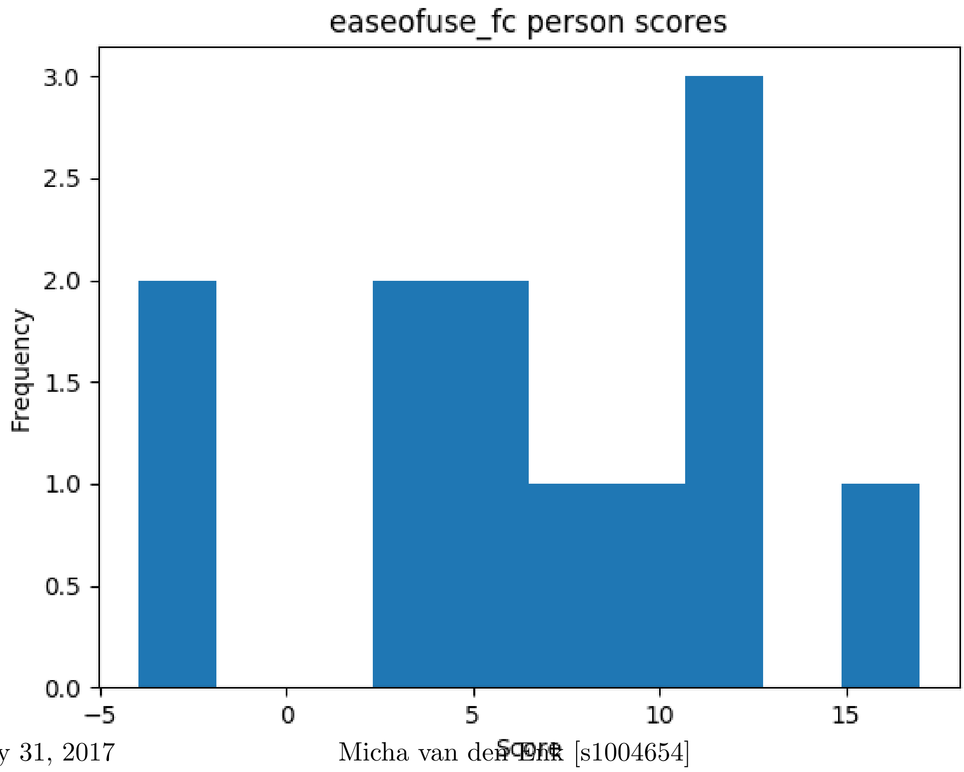
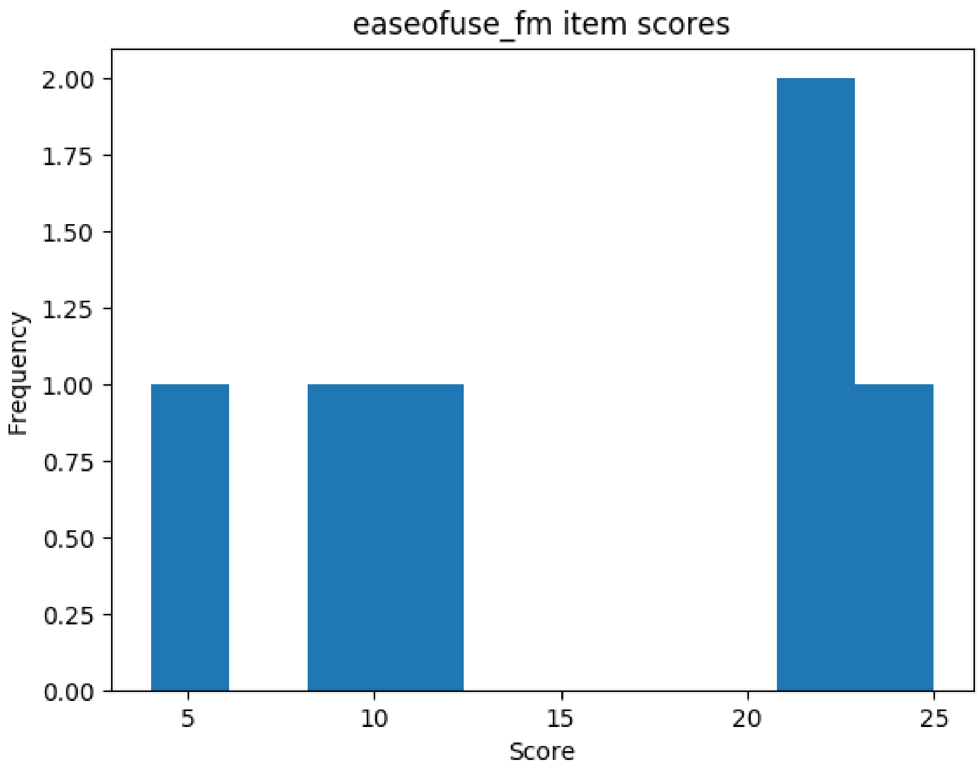

easeofuse_fc person scores
Frequency
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−5
0
5
10
15

Table 26: Flashmap condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	11	0	19	8.27	26.22	0.50	0.12	1.725	0.4220	0.7689
irt	11	-2	2	0.22	1.87	-0.20	1.01	3.041	0.2186	0.2538


easeofuse_fm item scores
Frequency
Score
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
5
10
15
20
25

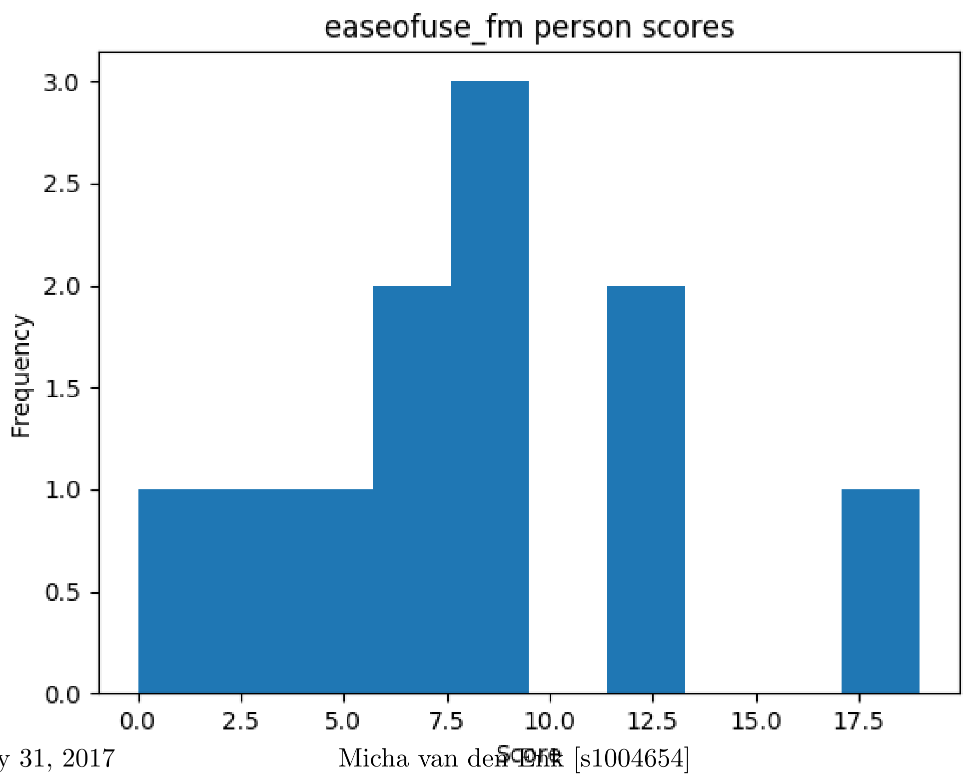
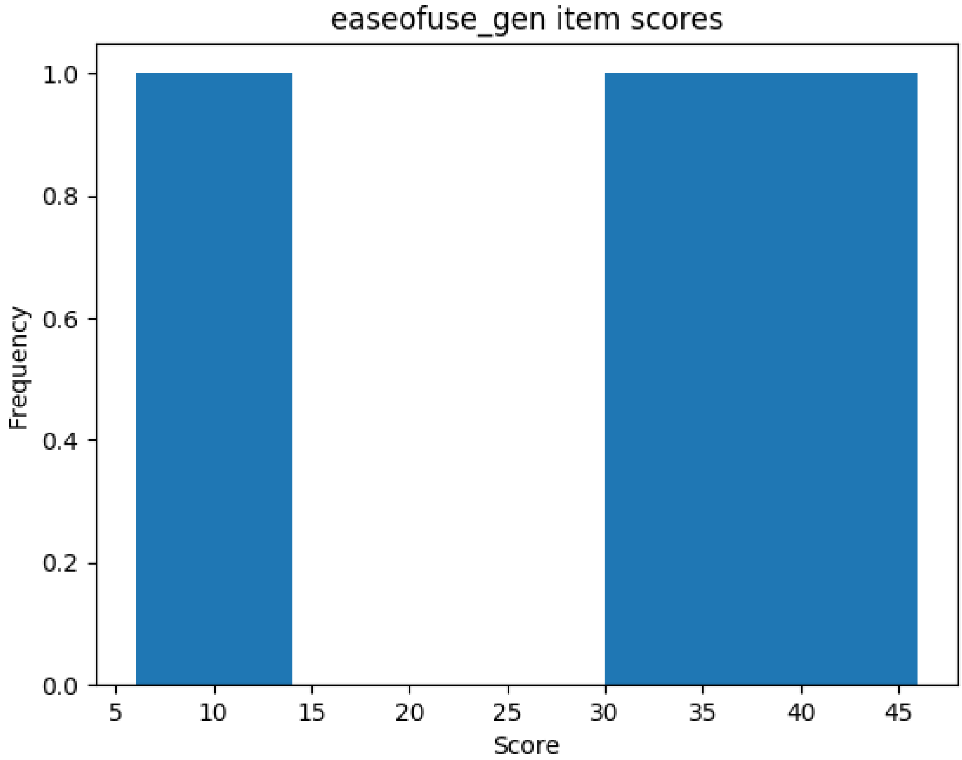
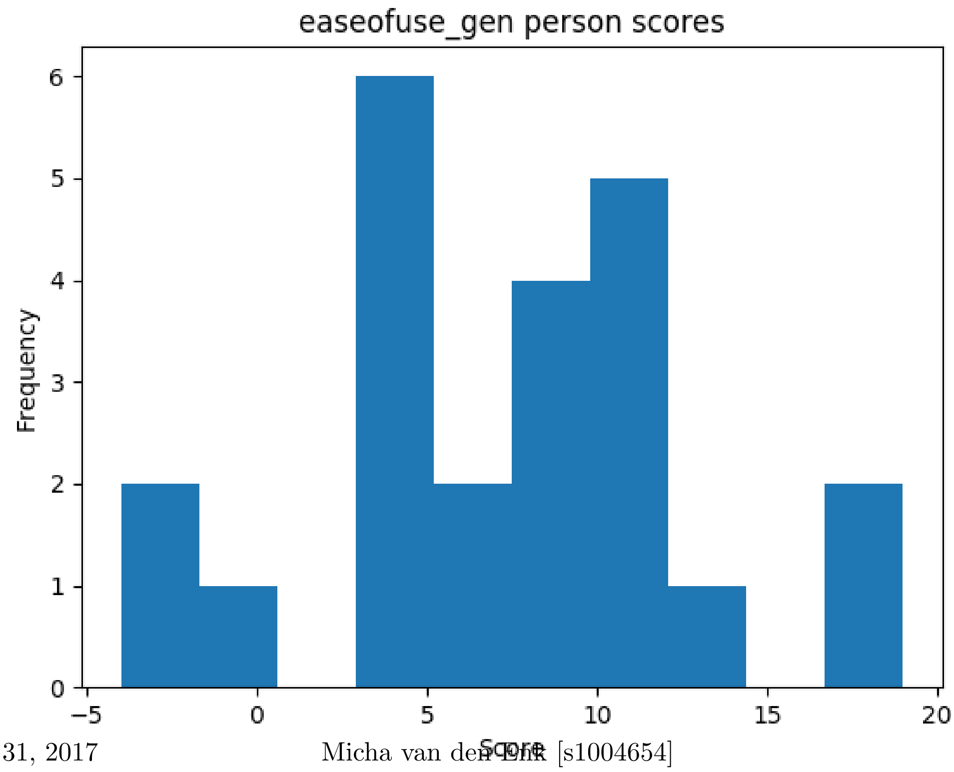

easeofuse_fm person scores
Frequency
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5

Table 27: Combined conditions

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
ctt	23	-4	19	7.39	31.70	-0.08	-0.10	0.239	0.8876	0.8285

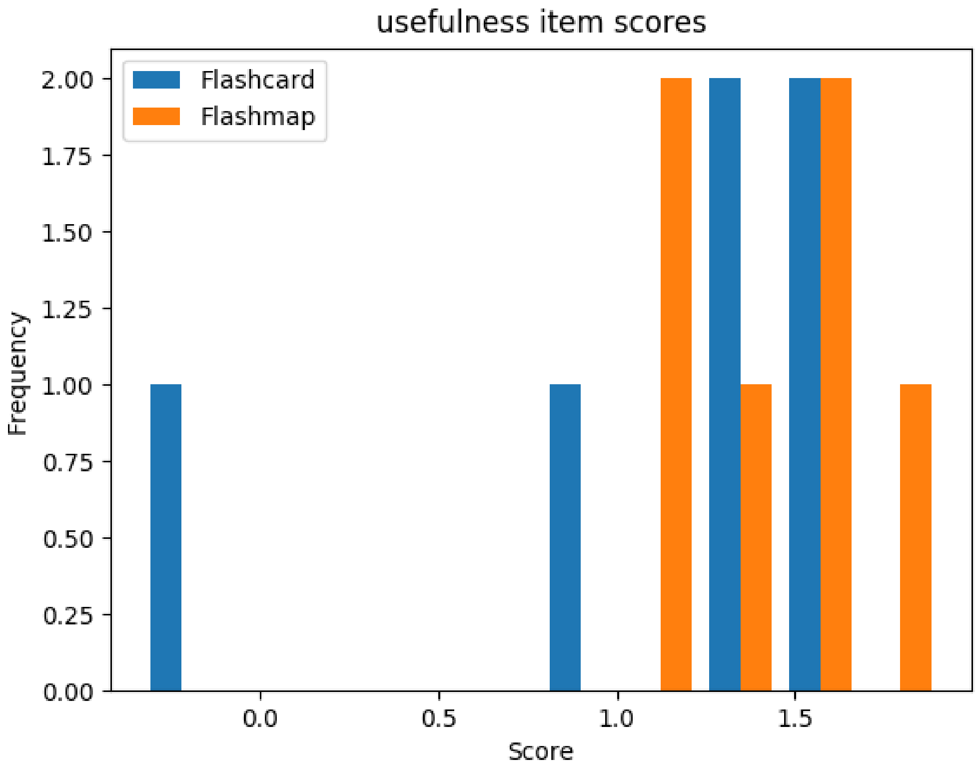

easeofuse_gen item scores
Frequency
Score
1.0
0.8
0.6
0.4
0.2
0.0
5
10
15
20
25
30
35
40
45

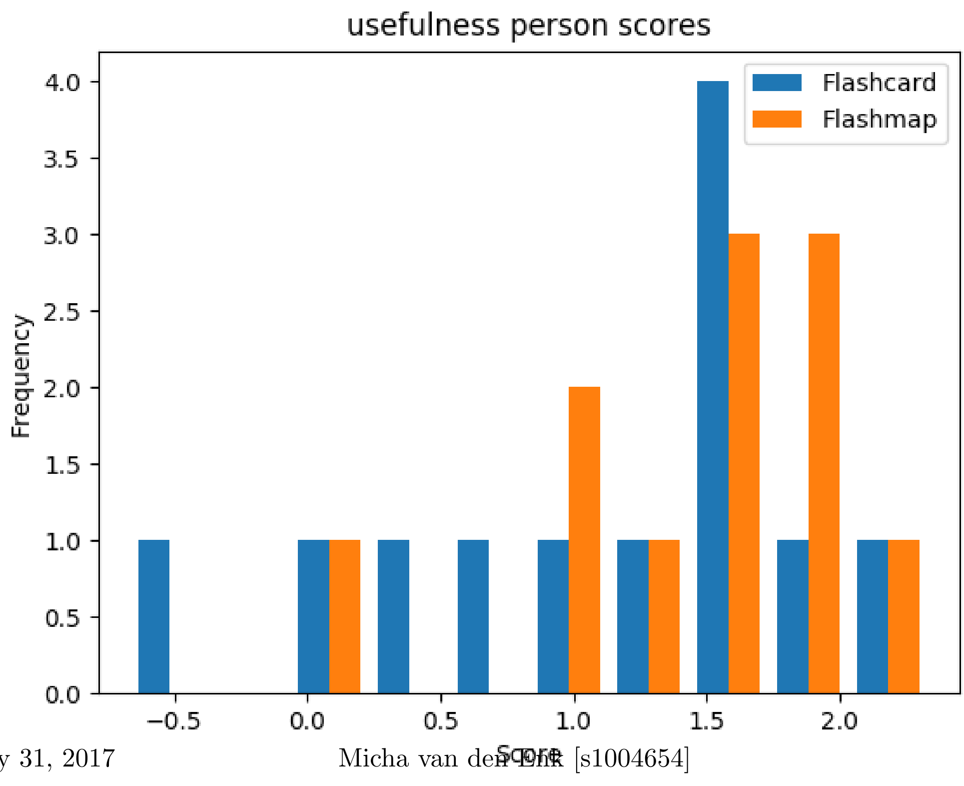

easeofuse_gen person scores
Frequency
Score
6
5
4
3
2
1
0
−5
0
5
10
15
20

a2d1a05

Comparisons of the Perceived Usefulness questions

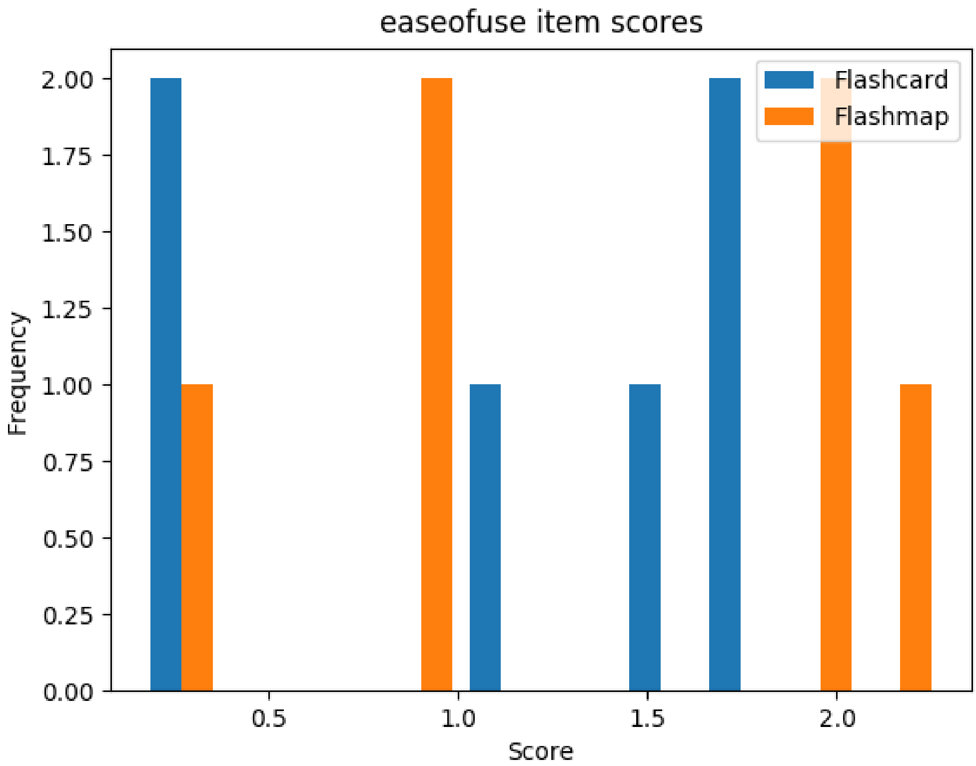
	MW k	**MW p**	**t-test k**	**t-test p**
ctt	-1.196	0.2449	-1.212	0.2395
irt	-0.014	0.9891	-0.014	0.9889

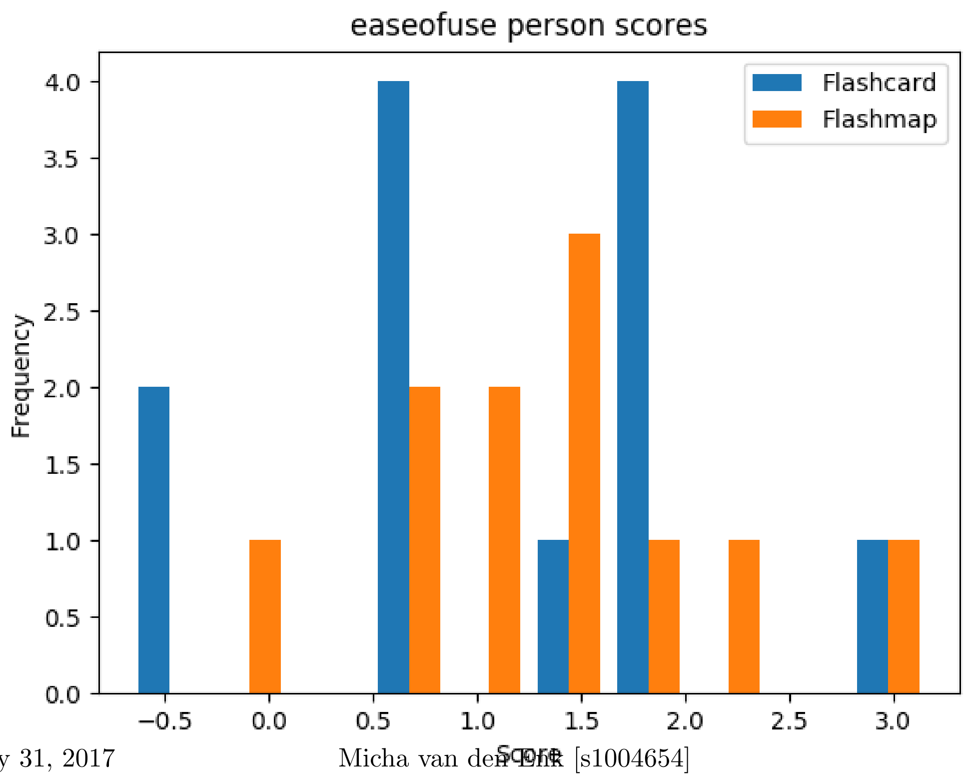

usefulness item scores
Flashcard
Flashmap
Frequency
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
Score


usefulness person scores
Flashcard
Flashmap
Frequency
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.0
0.5
1.0
1.5
2.0
Score

Comparisons of the Perceived Usefulness questions

	MW k	MW p	t-test k	t-test p
ctt	-0.711	0.4851	-0.717	0.4816
irt	1.206	0.2411	1.206	0.2412


easeofuse item scores
Flashcard
Flashmap
Frequency
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.5
1.0
1.5
2.0
Score


easeofuse person scores
Flashcard
Flashmap
Frequency
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Score

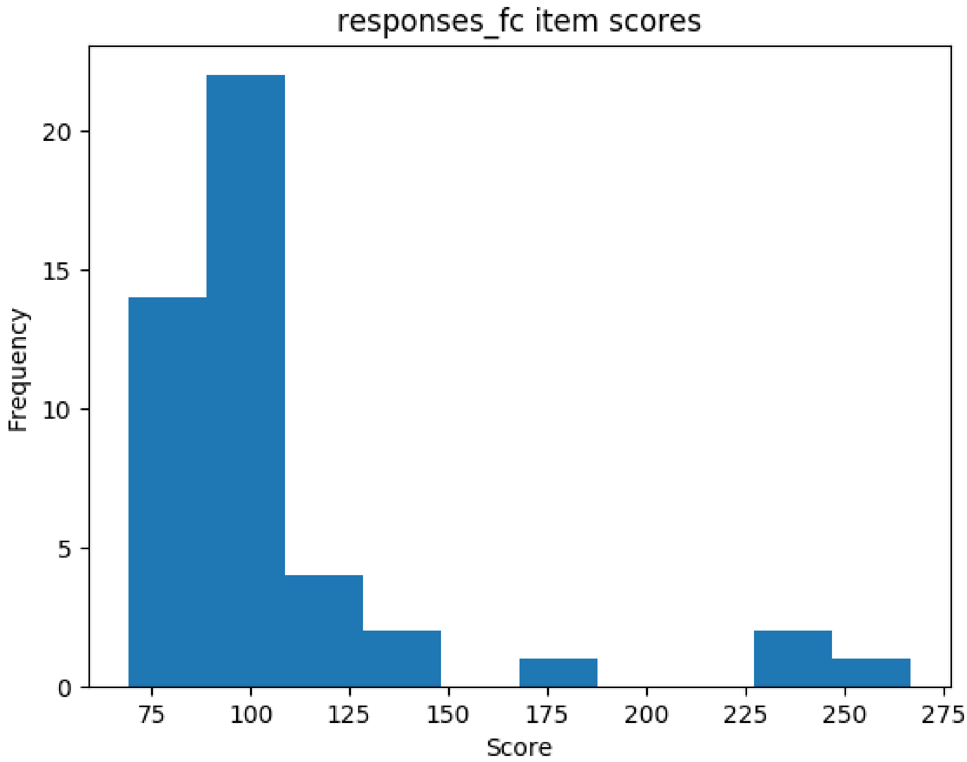
a2d1a05

Instance statistics

Descriptives of the number of responses

Table 30: Flashcard condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	12	298	915	408.17	28248.33	2.53	5.26	26.675	0.0000	0.8557
rel	12	6	19	8.87	13.35	2.53	5.26	26.675	0.0000	0.8557


responses_fc item scores
Frequency
0
5
10
15
20
75
100
125
150
175
200
225
250
275
Score

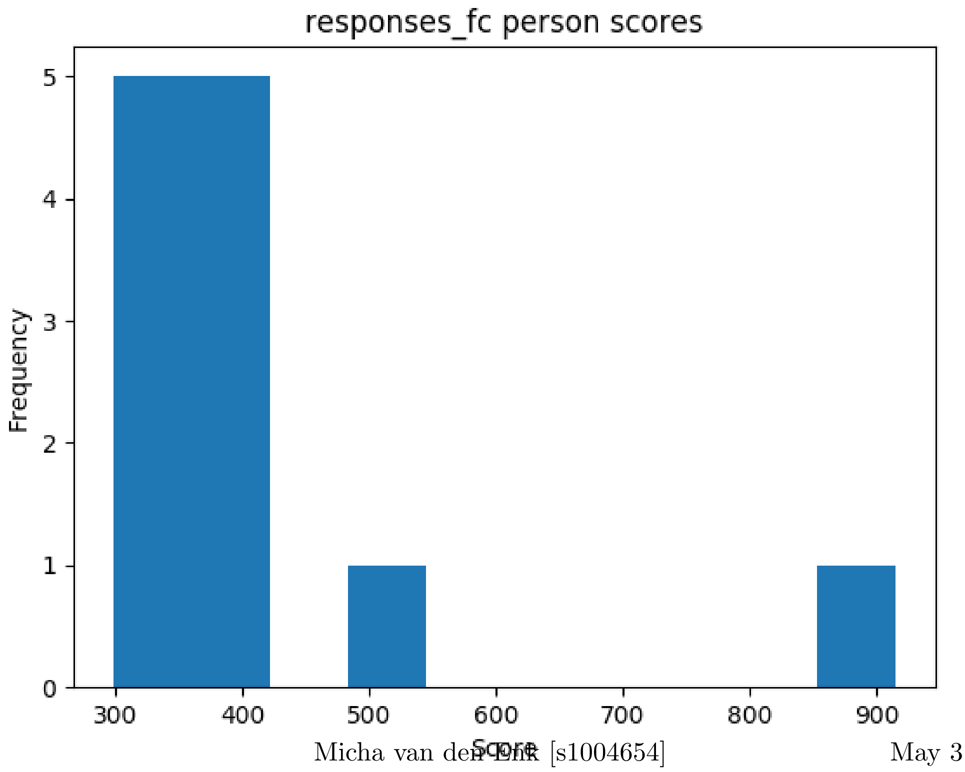
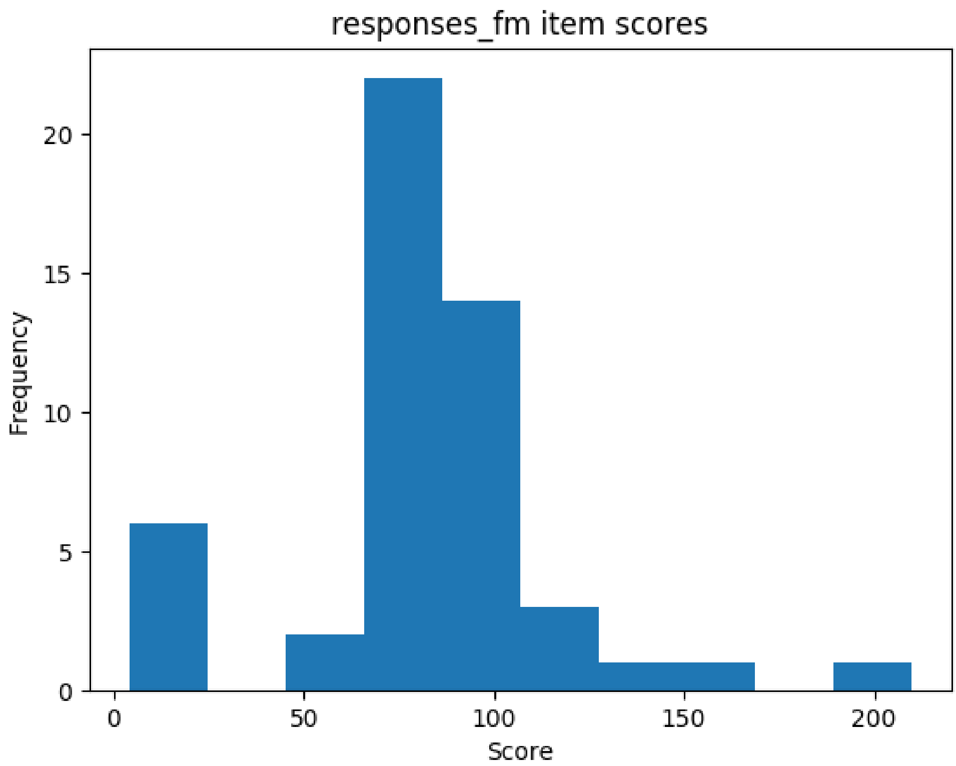
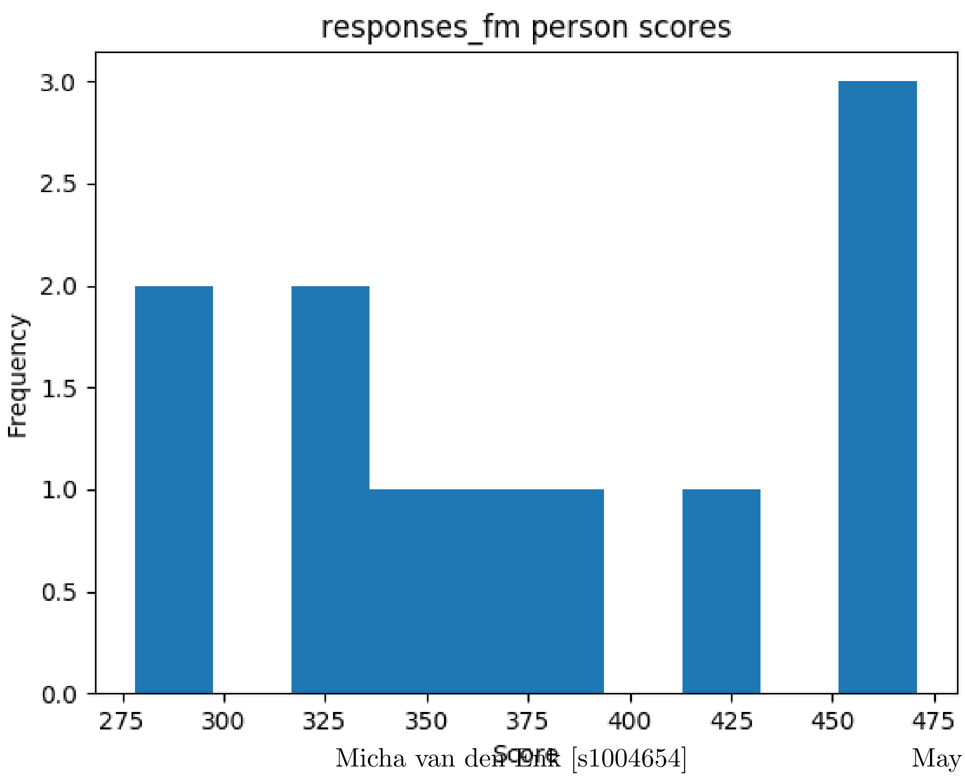

responses_fc person scores
Frequency
0
1
2
3
4
5
300
400
500
600
700
800
900
Score

Table 31: Flashmap condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	11	278	471	374.36	4875.05	0.13	-1.28	1.516	0.4686	0.7098
rel	11	5	9	7.49	1.95	0.13	-1.28	1.516	0.4686	0.7098



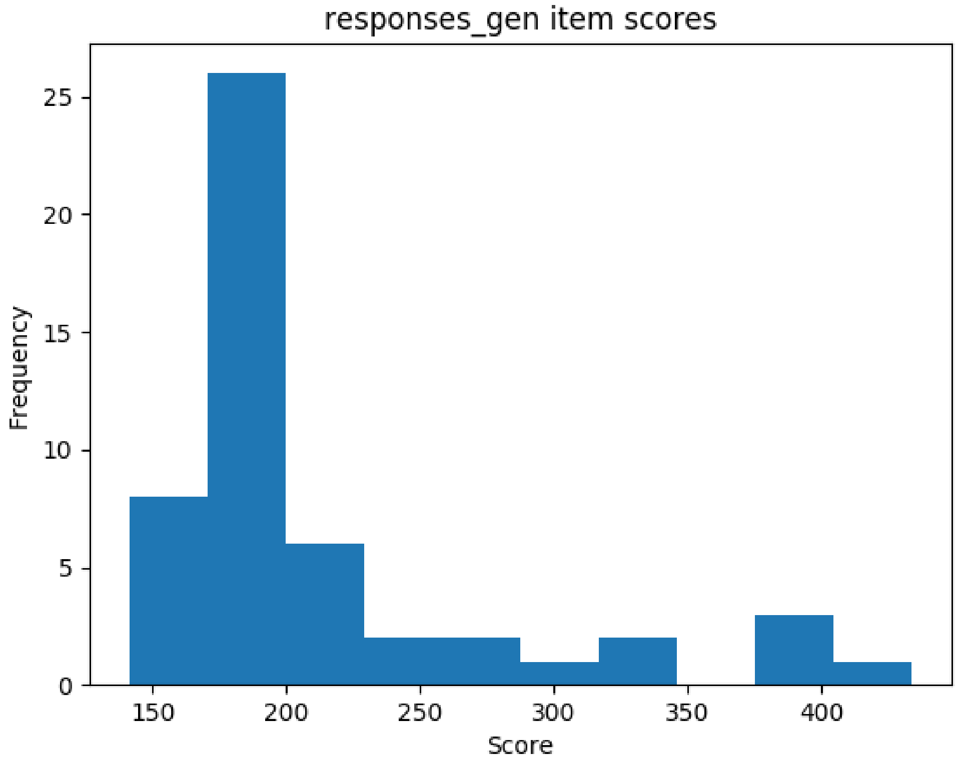
responses_fm item scores
Frequency
0
5
10
15
20
0
50
100
150
200
Score

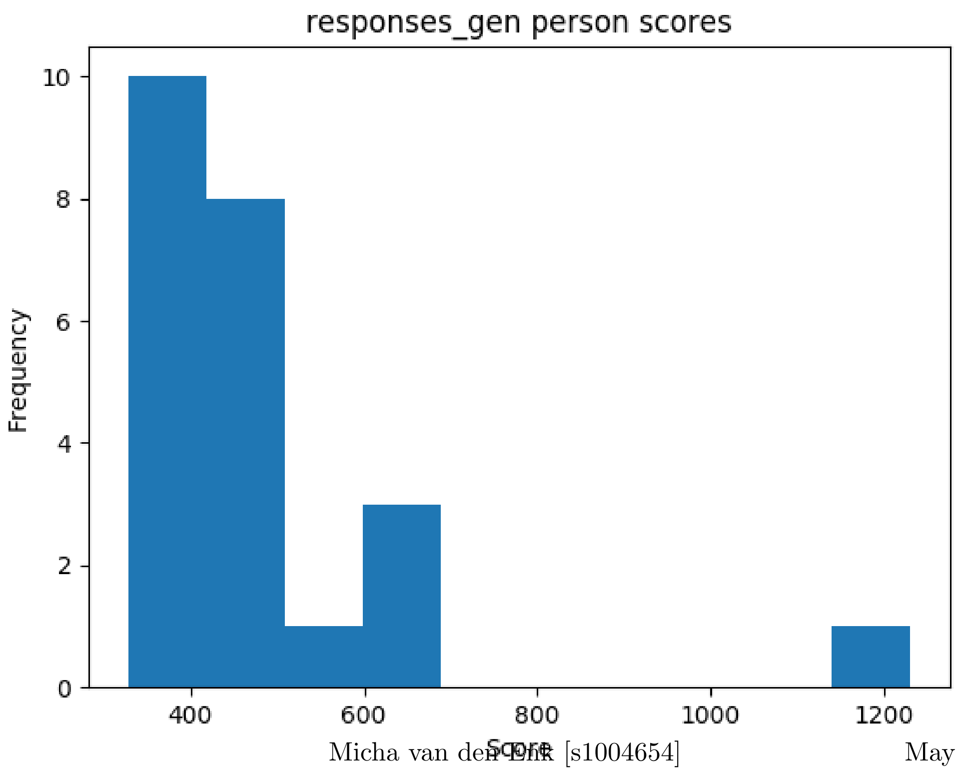


responses_fm person scores
Frequency
0.0
0.5
1.0
1.5
2.0
2.5
3.0
275
300
325
350
375
400
425
450
475
Score

Table 32: Combined conditions

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	23	328	1230	474.74	34192.57	3.12	10.33	41.081	0.0000	0.8731
rel	23	6	24	9.31	13.15	3.12	10.33	41.081	0.0000	0.8731

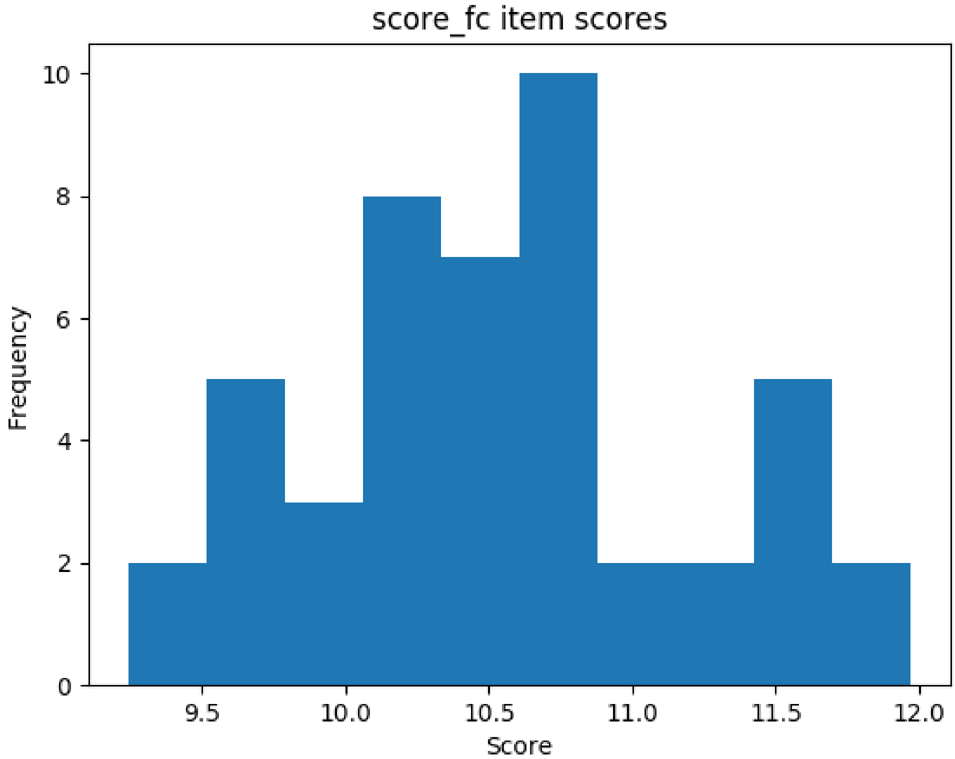

responses_gen item scores
Frequency
0
5
10
15
20
25
150
200
250
300
350
400
Score


responses_gen person scores
Frequency
0
2
4
6
8
10
400
600
800
1000
1200
Score

Descriptives of percentage of responses marked as correct

Table 33: Flashcard condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	12	35	43	40.42	4.04	-1.15	1.74	8.672	0.0131	0.9106
rel	12	0	0	0.88	0.00	-1.15	1.74	8.672	0.0131	0.9106


score_fc item scores
Frequency
Score
0
2
4
6
8
10
9.5
10.0
10.5
11.0
11.5
12.0

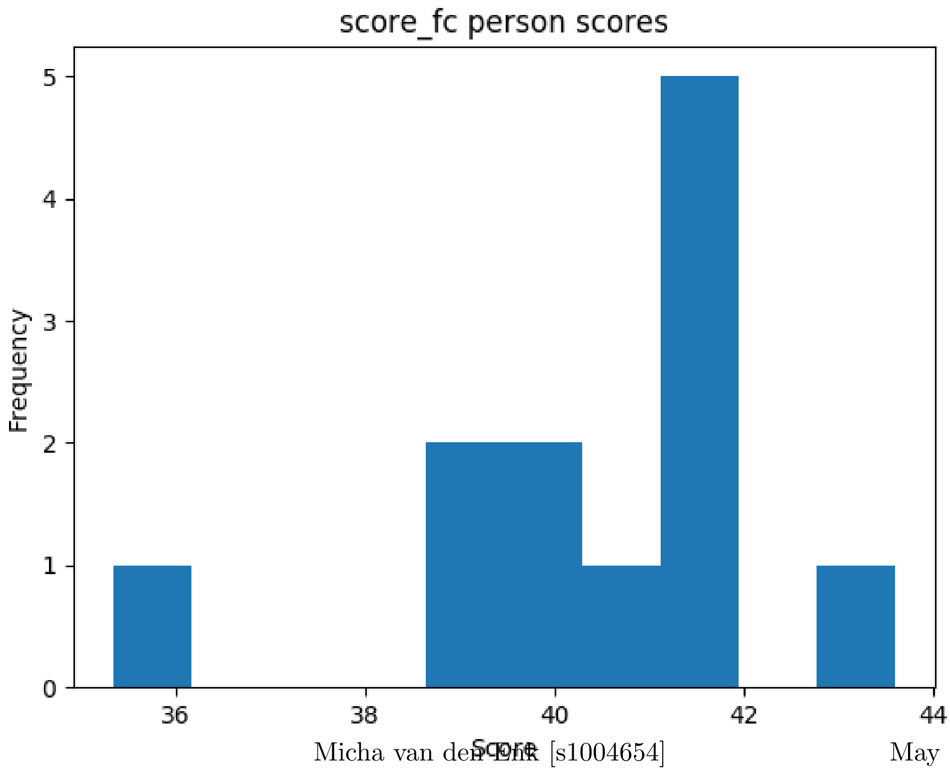
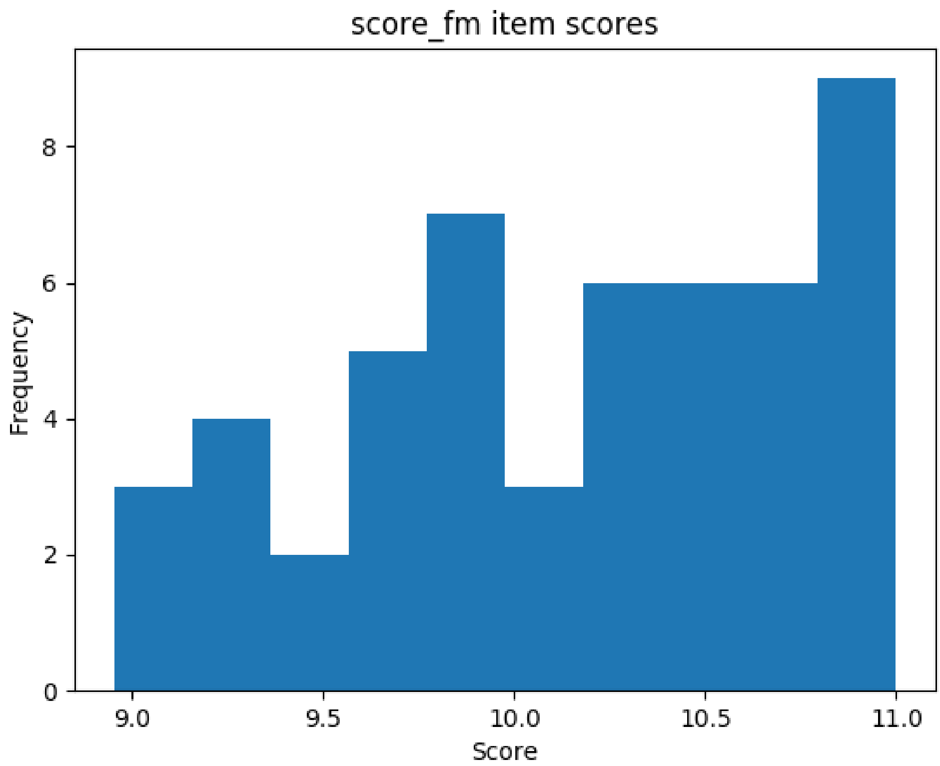

score_fc person scores
Frequency
Score
0
1
2
3
4
5
36
38
40
42
44

Table 34: Flashmap condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	11	43	51	47.11	6.19	0.31	-1.17	1.231	0.5404	0.9511
rel	11	0	1	0.92	0.00	0.31	-1.17	1.231	0.5404	0.9511


score_fm item scores
Frequency
0
2
4
6
8
9.0
9.5
10.0
10.5
11.0
Score

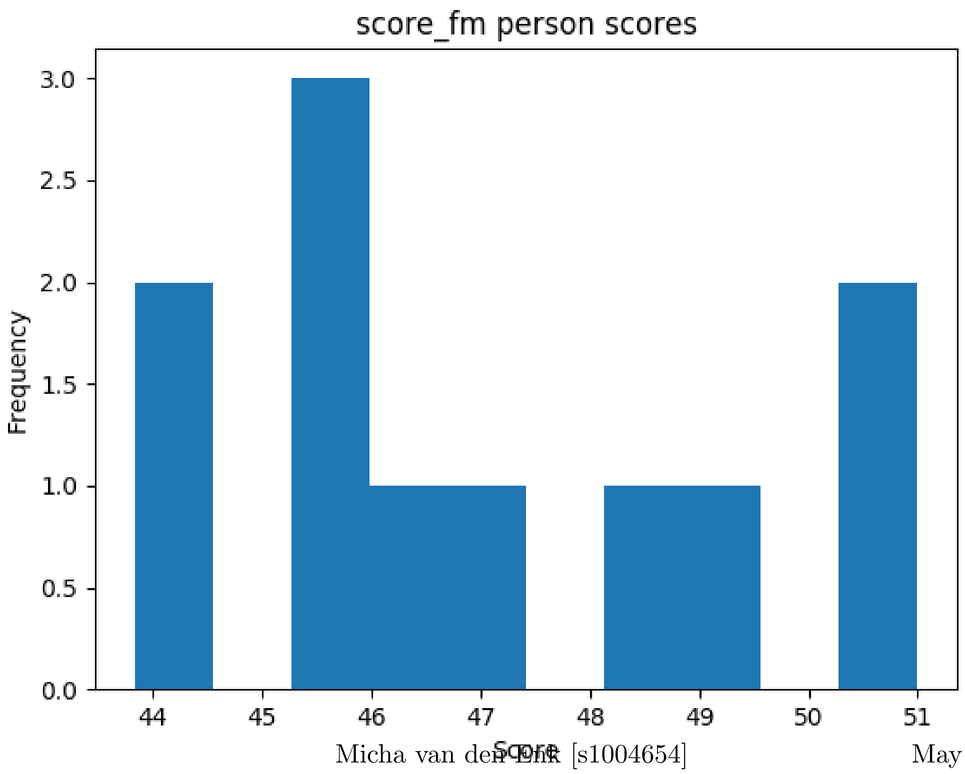
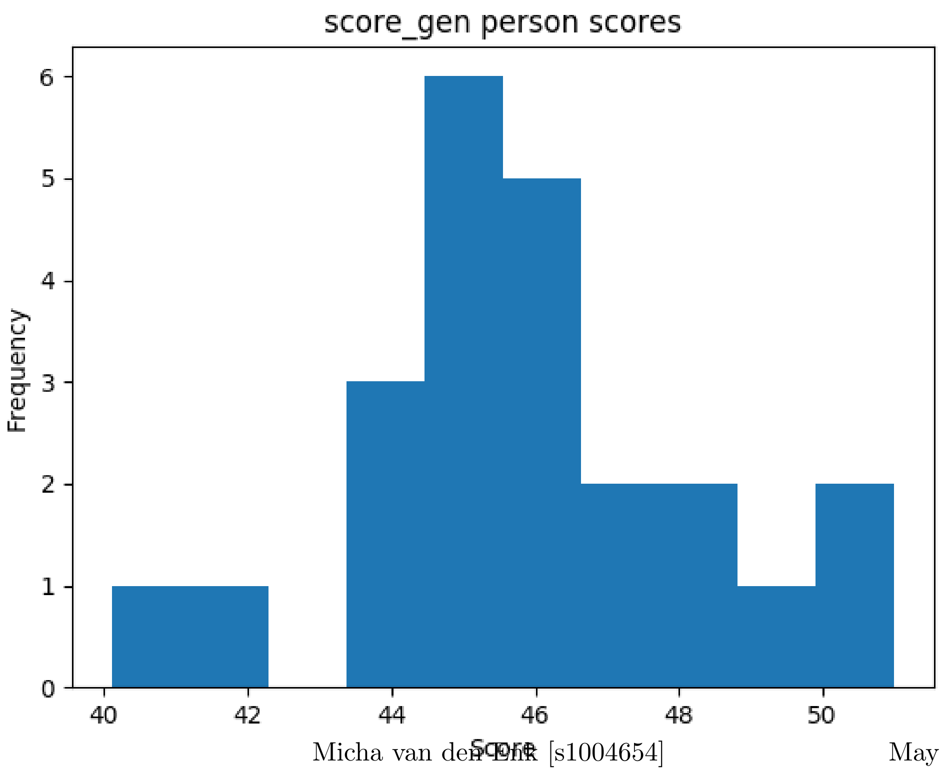

score_fm person scores
Frequency
0.0
0.5
1.0
1.5
2.0
2.5
3.0
44
45
46
47
48
49
50
51
Score

Table 35: Combined conditions

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	23	40	51	45.97	6.47	0.06	0.22	0.711	0.7008	0.9459
rel	23	0	1	0.90	0.00	0.06	0.22	0.711	0.7008	0.9459

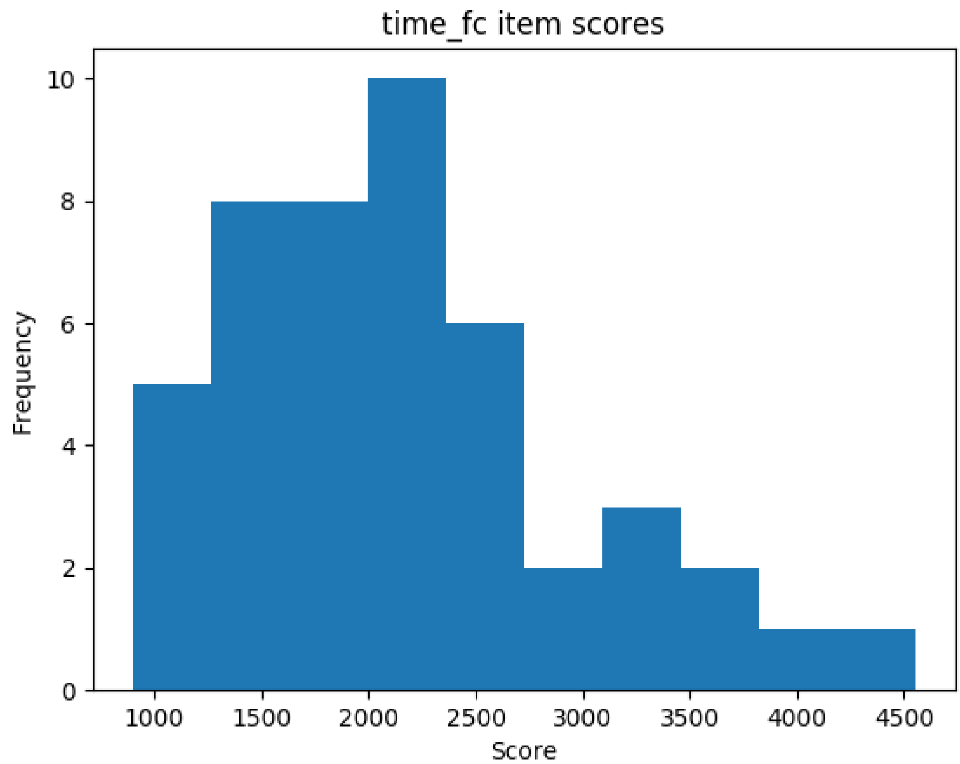

score_gen item scores
Frequency
Score
0
2
4
6
8
10
19.0
19.5
20.0
20.5
21.0
21.5
22.0
22.5
23.0


score_gen person scores
Frequency
Score
0
1
2
3
4
5
6
40
42
44
46
48
50

Descriptives of the amount of time spent on the application

Table 36: Flashcard condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	12	1544	12345	8173.94	10611999.29	-0.77	-0.33	2.156	0.3402	0.8776
rel	12	33	268	177.69	5015.12	-0.77	-0.33	2.156	0.3402	0.8776


time_fc item scores
Frequency
Score
0
2
4
6
8
10
1000
1500
2000
2500
3000
3500
4000
4500

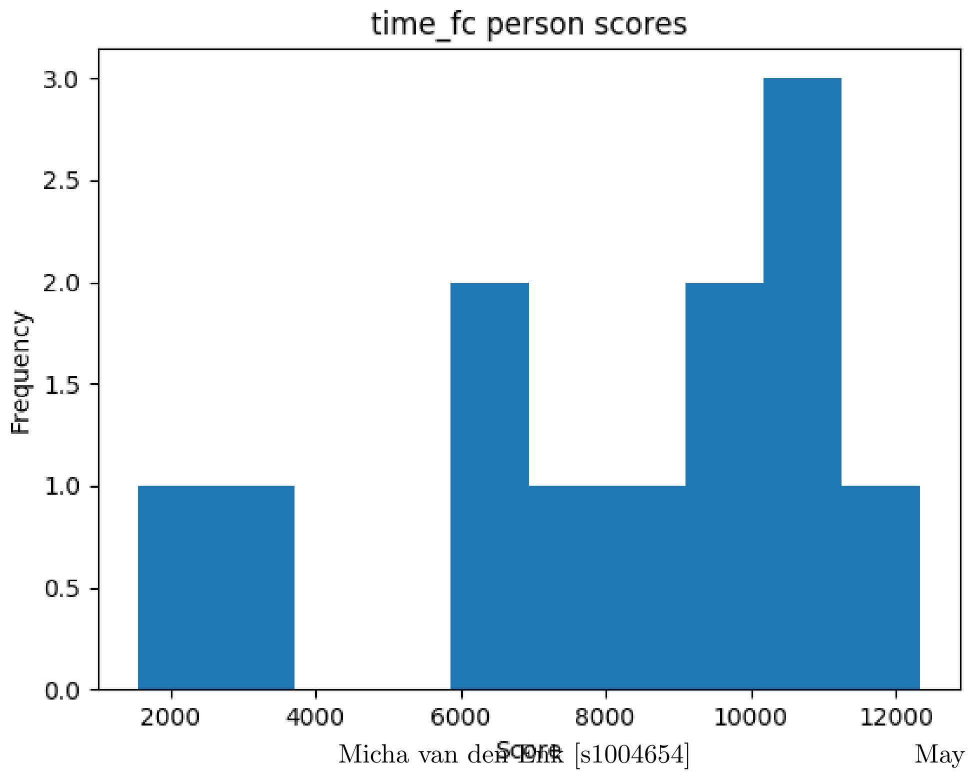
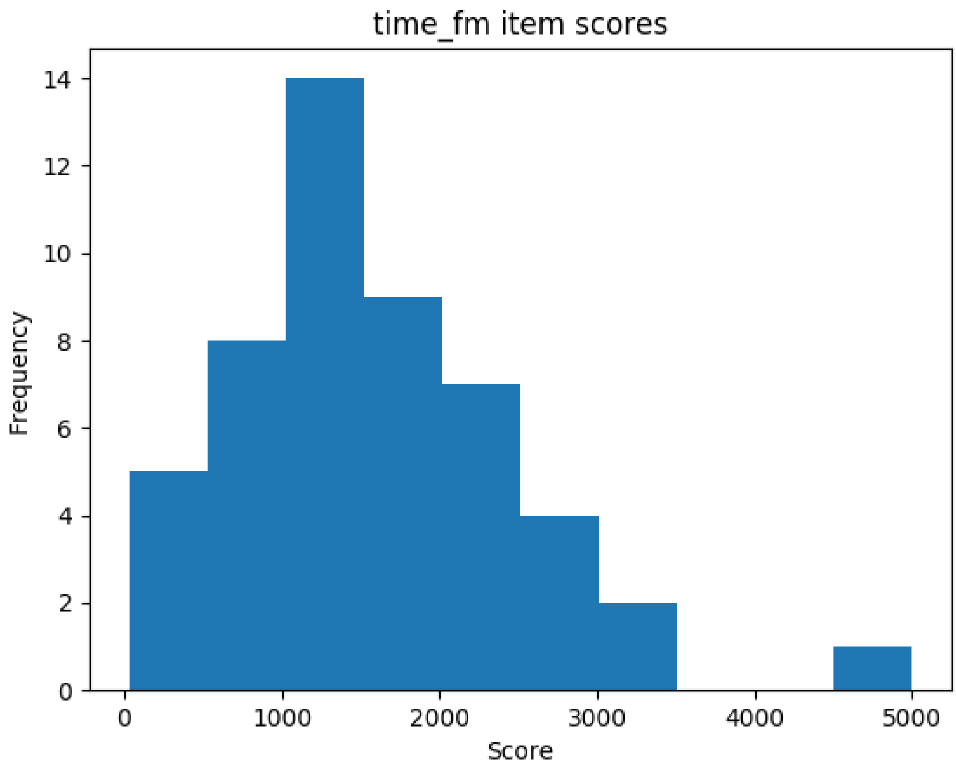

time_fc person scores
Frequency
Score
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2000
4000
6000
8000
10000
12000

Table 37: Flashmap condition

	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	11	1707	12233	7221.30	8917086.17	0.05	-0.44	0.092	0.9551	0.8268
rel	11	34	244	144.43	3566.83	0.05	-0.44	0.092	0.9551	0.8268


time_fm item scores
Frequency
Score
0
2
4
6
8
10
12
14
0
1000
2000
3000
4000
5000

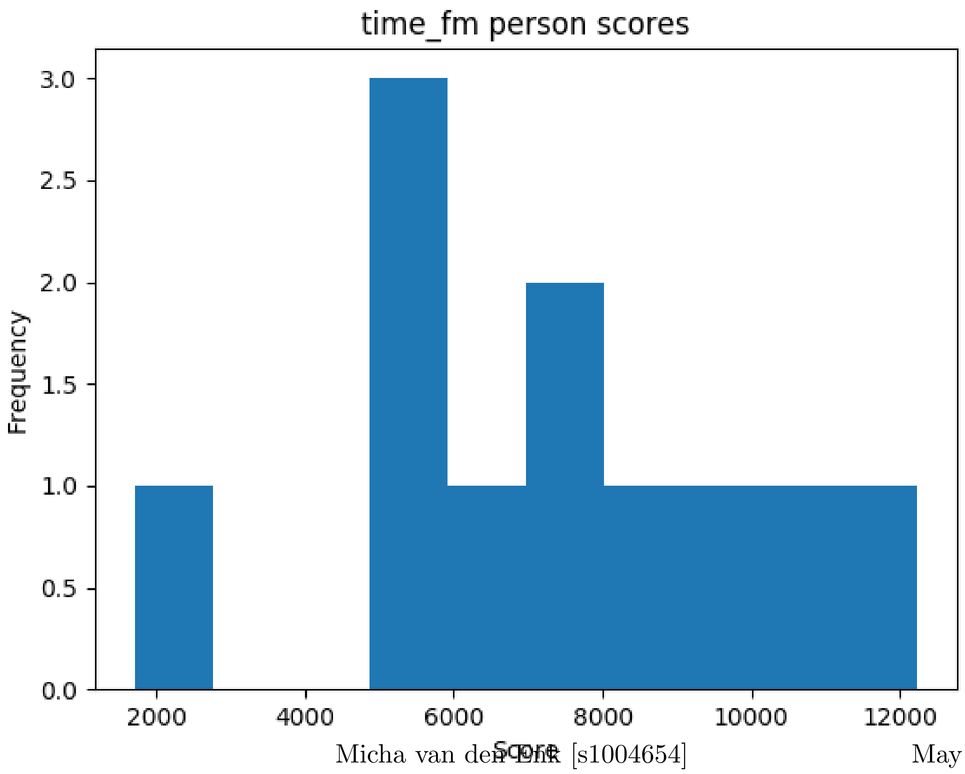
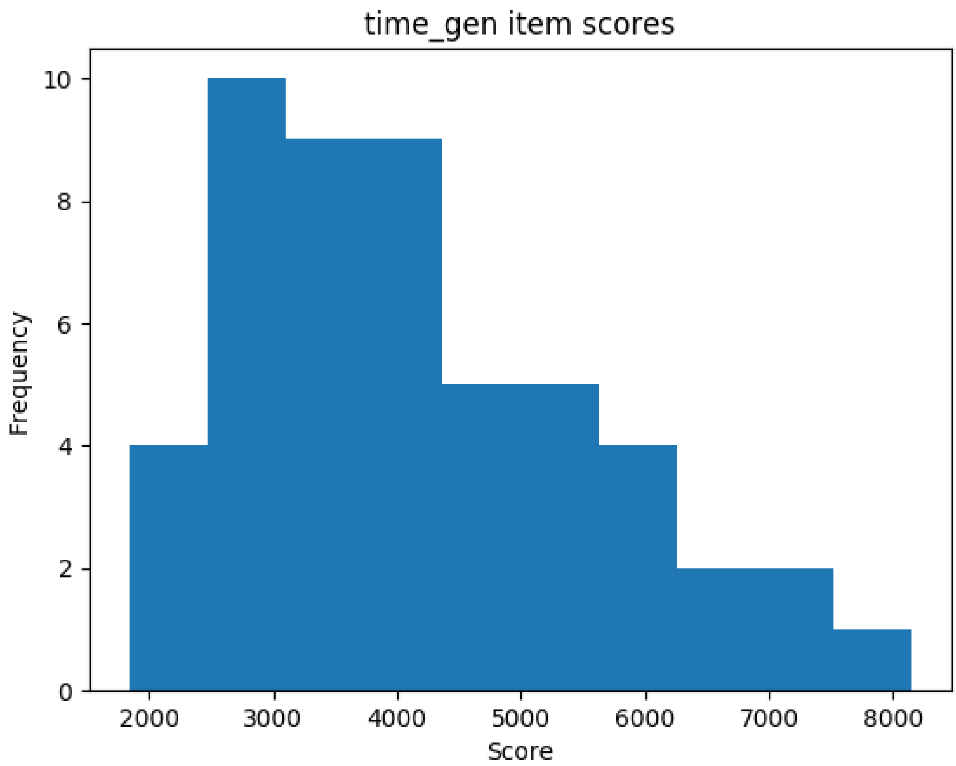
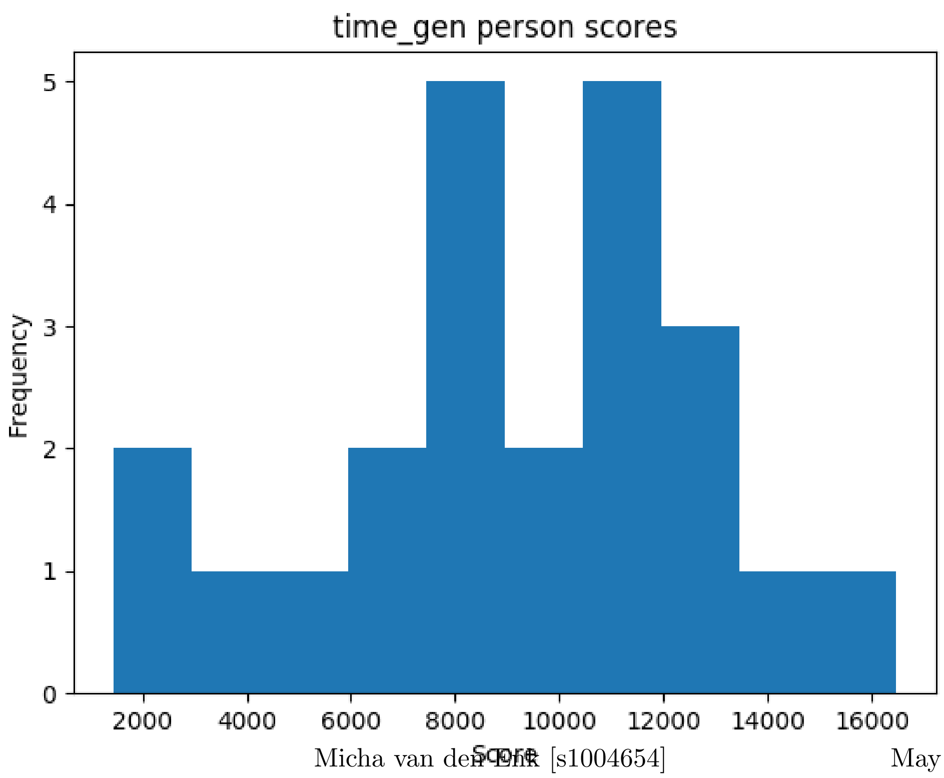

time_fm person scores
Frequency
Score
0.0
0.5
1.0
1.5
2.0
2.5
3.0
2000
4000
6000
8000
10000
12000

Table 38: Combined conditions

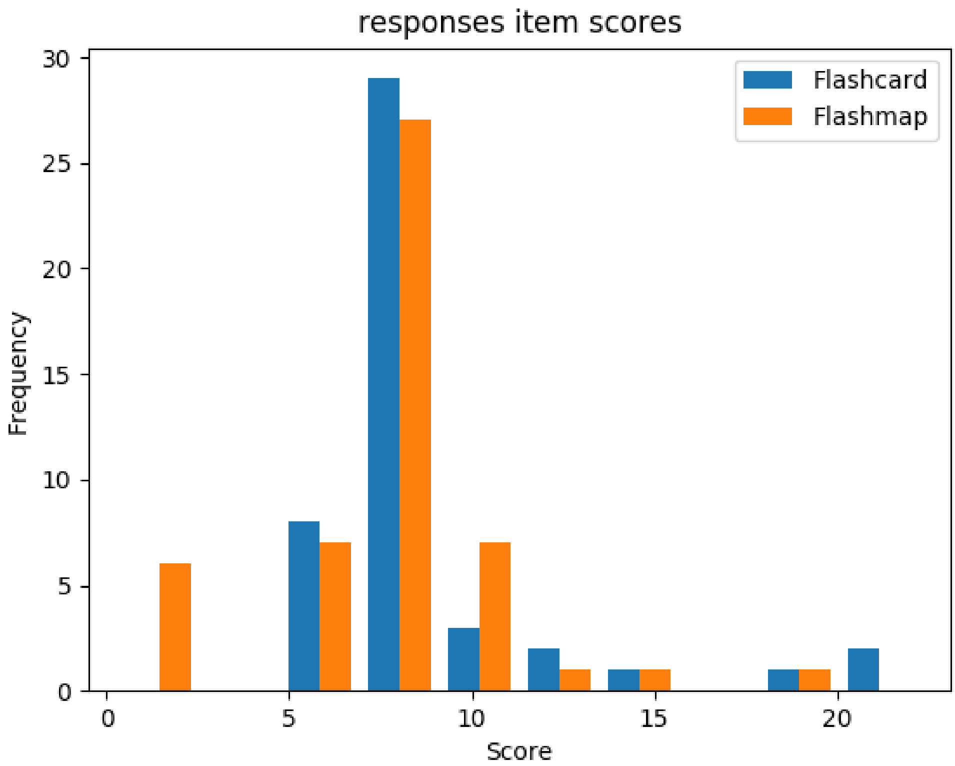
	N	min	max	mean	variance	skew	kurt	norm-t	norm-p	α
abs	23	1426	16484	9283.95	14203173.83	-0.31	-0.29	0.544	0.7617	0.8591
rel	23	27	323	182.04	5460.66	-0.31	-0.29	0.544	0.7617	0.8591

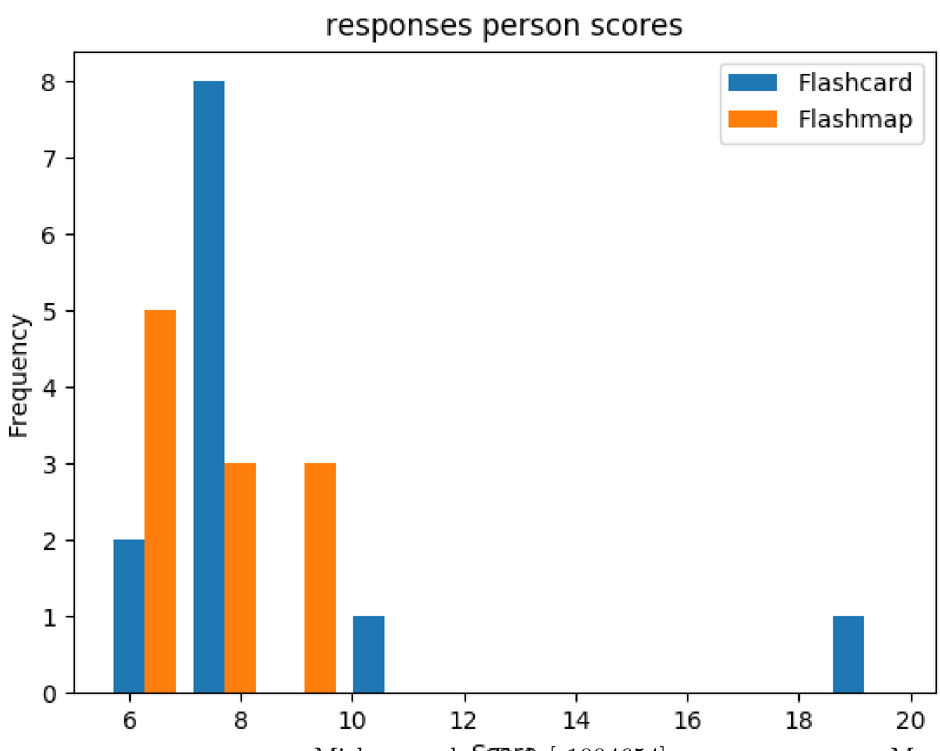

time_gen item scores
Frequency
10
8
6
4
2
0
2000
3000
4000
5000
6000
7000
8000
Score


time_gen person scores
Frequency
5
4
3
2
1
0
2000
4000
6000
8000
10000
12000
14000
16000
Score

Comparisons of the number of responses

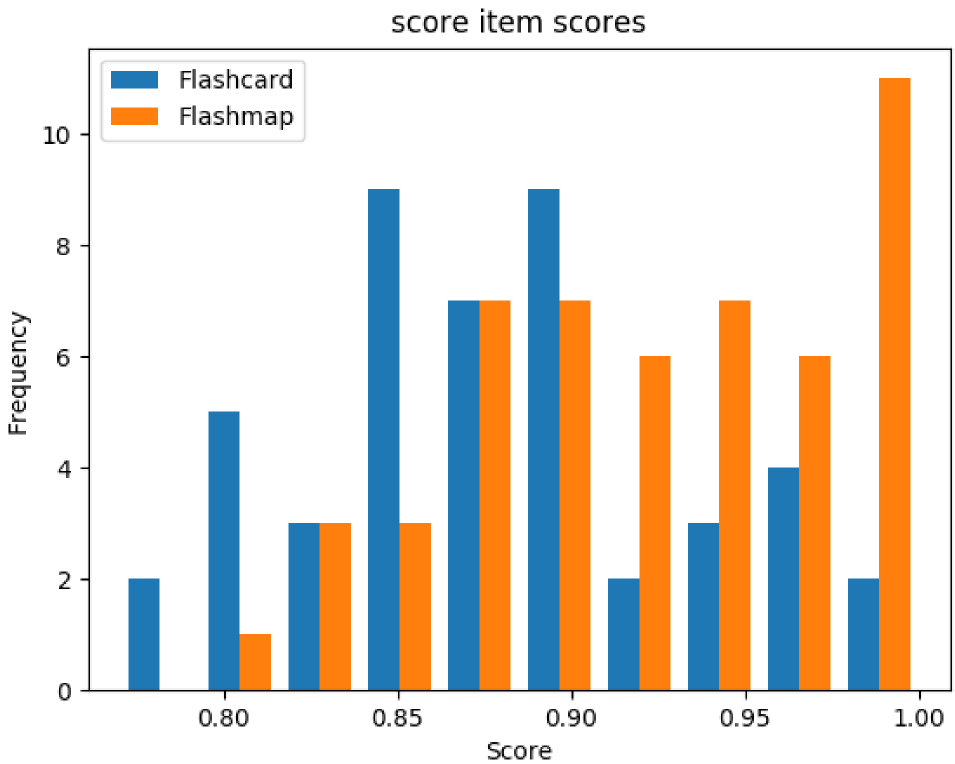
	MW k	MW p	t-test k	t-test p
abs	0.619	0.5426	0.639	0.5324
rel	1.180	0.2513	1.220	0.2420

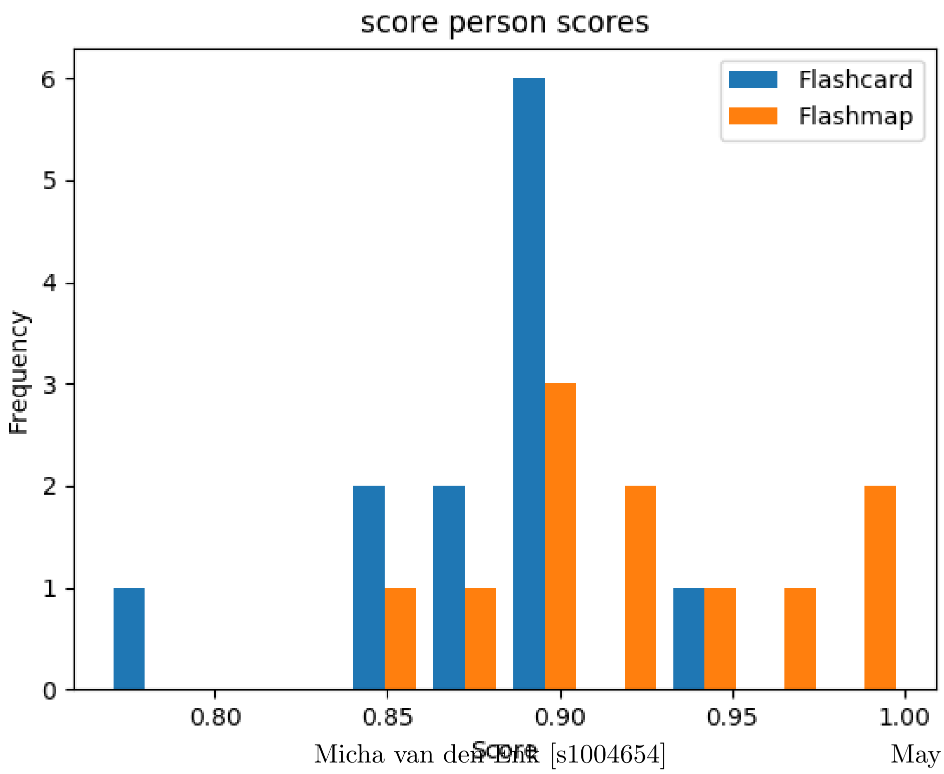

responses item scores
Flashcard
Flashmap
Frequency
Score
0
5
10
15
20
25
30


responses person scores
Flashcard
Flashmap
Frequency
Score
6
8
10
12
14
16
18
20

Comparisons of the percentage of responses marked as correct

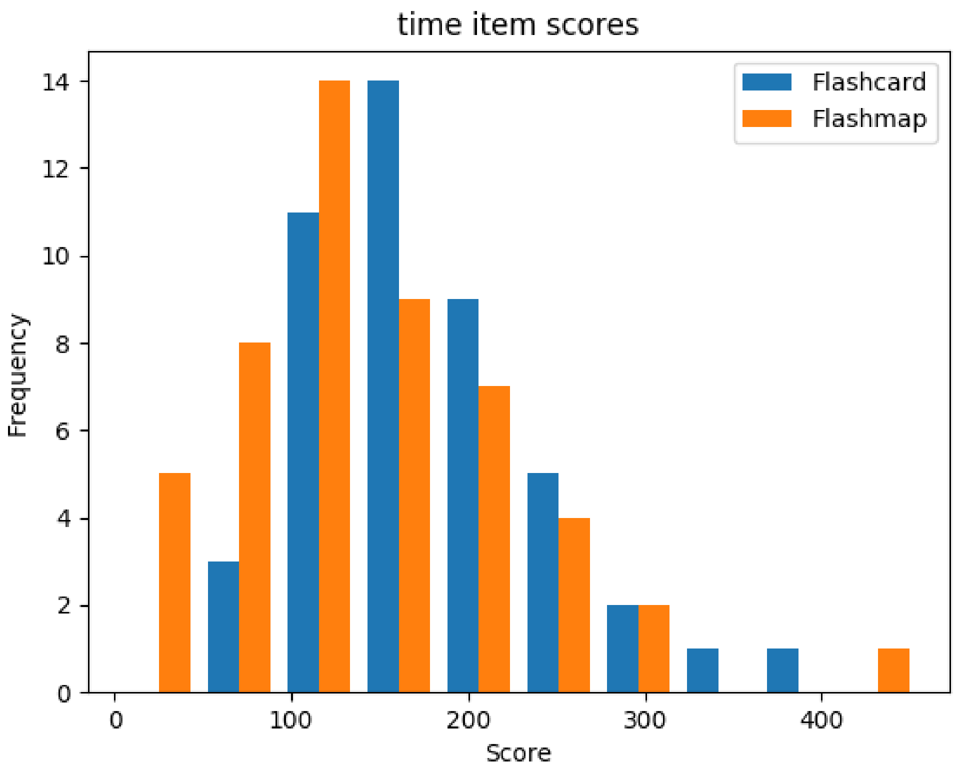
	MW k	**MW p**	**t-test k**	**t-test p**
abs	-16.597	0.0000	-15.857	0.0000
rel	-16.421	0.0000	-15.689	0.0000

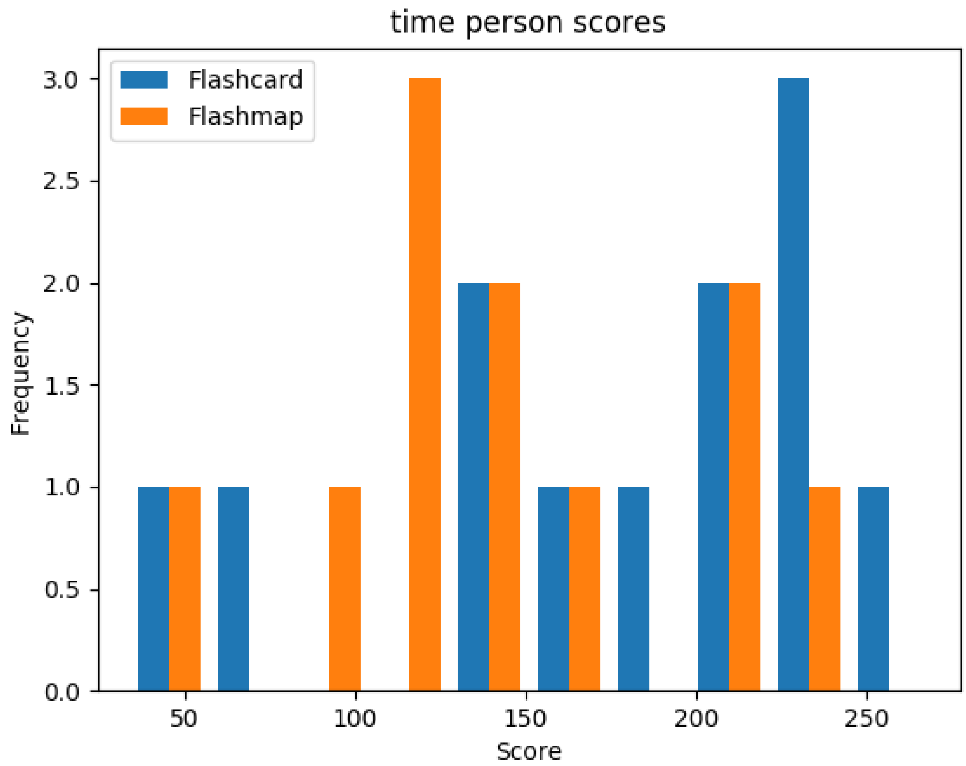

score item scores
Flashcard
Flashmap
Frequency
Score
0
2
4
6
8
10
0.80
0.85
0.90
0.95
1.00


score person scores
Flashcard
Flashmap
Frequency
Score
0
1
2
3
4
5
6
0.80
0.85
0.90
0.95
1.00

Comparisons of the amount of time spent on the application

	MW k	MW p	t-test k	t-test p
abs	7.924	0.0000	8.292	0.0000
rel	7.954	0.0000	8.324	0.0000




time person scores
Flashcard
Flashmap
Frequency
Score
3.0
2.5
2.0
1.5
1.0
0.5
0.0
50
100
150
200
250