Developing an educational tool to promote evidence-based treatment in health care

A pilot study

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Contents

Chapter 1

Introduction

1.1 Motivation

1.2 Research questions

- Can we make a data structure representing the paediatric possible asthma guideline Republic of Kenya 2016 in a very generic way?
- Based on the data structure, can we generate suitable scenarios, with multiple choice question with answer elements for training and evaluating health personnel?
- How can we structure the learning material to best train medical students, doctors, clinical officers, nurses and other health workers in the paediatric possible asthma guideline Republic of Kenya 2016?

1.3 Structure of the thesis

Chapter 2

Background

2.1 Clinical Practice Guidelines

For a clinician, Fervers, Carretier, and Bataillard (2010) claims that increased medical knowledge is associated with an exponential growth of scientific data and published material. It is impossible to keep up, as well as integrating all the new information into daily practice to give patients the best possible care. Masic, Miokovic, and Muhamedagic (2008) gives an example where a general practitioner should read 19 articles per day to keep up with the new medical information, while only having time to read one hour per week. The clinician will spend more time reading articles than treating patients.This problem is known as academic isolation.

Evidence Based Medicine (EBM) suggests that instead of routinely reading dozens of articles, the clinicians should target their reading to specific patient problems. Developing clinical questions and then searching for the answer (problem based approach), may be a more productive way to keep up with the new medical knowledge (Masic, Miokovic, and Muhamedagic 2008). The EBM definition further puts an emphasize on integrating the best evidence in decision making with the clinicians expertise and the patients values and expectations (Masic, Miokovic, and Muhamedagic 2008).

The concept of EBM is about transferring knowledge from clinical research into clinical practice, and Clinical Practice Guidelines (CPG) can play an instrumental role in this process (Fervers, Carretier, and Bataillard 2010).

The Institute of Medicine (IOM) has given the following definition of clinical practice guidelines: "CPGs are statements that include recommendations intended to optimize patient care. These statements are informed by a systematic review of evidence and an assessment of the benefits and costs of alternative care options" ((US) et al. 2011)

The definition given by IOM covers the goals in EBM, and also takes the cost into account. In fact, Clayton and Hripcsak (1995) have shown that in some situations good use of appropriate guidelines and protocols can reduce as much as 25% of the cost of healthcare.

Even though the CPGs have proven to improve the quality of health care while reducing practice variability and the cost of patient care (De Clercq, Kaiser, and Hasman 2008), it is well recognized that CPGs have had a limited effect on changing the clinicians practice methods. Cabana et al. (1999) lists the following reasons:

- Lack of awareness.
- Lack of familiarity.

- Lack of agreement with the content.
- Lack of self-efficacy.
- Lack of outcome expectancy.
- Inertia of previous practice.
- External Barriers; the guidelines are not easy to use, not convenient, cumbersome and confusing.

One example of external barrier is the Guidelines for the Diagnosis and Management of Asthma (National Heart Lung and Blood Institute and U.S. Department of Health & Human Services 2007), which consists of 440 pages. Such a large journal is not convenient to use at the point of care. According to Shortliffe (1998), CPGs in monographs and journal articles tend to sit on book shelves at the time their knowledge could prove the most valuable to the clinicians.

- Medical knowledge increases. Hard to keep track
- Guidelines is a summary of the available evidence of the medical conditions and provide management and recommendations
- A well-developed guideline reduces variations in care, improves diagnostic accuracy, promotes effective therapy and discourages ineffective therapies all which contribute to improved quality of care (citation)
- The CPGs are not used enough
- Dissemination and implementation
- Large volume of excisting guidelines. Difficult to use at the point of care
- Dissemination
- Different practice even in the same country

2.2 Serious games

2.3 Asthma

2.3.1 Challenges

2.4 Related work

2.5 Summary

Chapter 3

Method

3.1 Design study

3.2 Focus group

The 25th of February 2018, we arranged a focus group at a kitchen in Alrek student home. The participants were:

- 6th year medical doctor student Fredrik Hoel.
- 6th year medical doctor student August Hoel.
- Master degree student in computer science Mohnd Skr.
- Master degree student in computer science Ben-Richard Ebbesvik.

As the project was in a very early stage, the purpose of the meeting was just exploring topics. How the CPGs are used today. How the students work in their practice periods at the hospital. What format are the CPGs in now. What challenges limits the use of CPGs among health workers and medical students at the point of care.

By using a an unstructured interview form, we managed to collect broad and general information, as well as going into detail on interesting topics. As the focus group was small, the contestants could discuss between themselves, highlighting consensus and conflicts Preece, Sharp, and Rogers 2015. A very free and exploitative approach was very successful, as the knowledge of the master degree students in computer science, were quite limited compared to the knowledge of the medical students. The discussion was documented using an audio recorder.

Topics explored:

- The students are learning new medical routines by studying typical cases. Drilling the routines.
- Red and yellow flags, which are alarm systems they need to be aware of. A red flag is when the patient's condition is quite critical. What triggers the flags and how to act upon them is something the clinicians need to know by heart, as time is critical and the action needed might be advanced like surgery. No time to use the guidelines.

- They a collection of short guidelines in a pocket book format for references. The guidelines are written mostly in text format and sometimes takes use of tables for presentation.

- Mobile devices can't be used at the point of care because of condemnation risks. There are also techniques of consultant with a patient. A mobile device will get in the way for important non-verbal communication.

- For departments they need access to specific cases where there isn't much written material. They need access to scientific articles.

- They brought up the case where doctors in developing countries have so many patients, and the time to each patient is very limited. To be able to look up information in the guidelines, they need to have a format which makes it very fast to extract that kind of information. Flow-charts is more suitable for developing countries where acting quickly is more often important than in developed countries where they can have a focus on being more thorough in green flag situations.

- In some situations the treatment a patient receives can be different depending on where in the country you are. For a patient with a blood clot, the medical personnel in Finnmark will start removing the blood clot immediately, because of the long distance to the nearest hospital. They want to reduce the risk for complications. While in Bergen, they will wait with such a treatment. In developing countries you might have to put into consideration what kind of equipment and staff is available at that specific hospital or health care station. The likelihood of different diseases is different from each geographically position, the patients background or the season in the year. Social and economic status also matters, even in Norway.

- Discussion about presentation of learning material in an application. Medical cases are often too obvious, too simple or too complicated in existing applications. Flash-cards. Show image of an ECG or a picture of a symptom.

- Notifying the student about guidelines would be useful. But only for the most common and dangerous conditions, relevant for the students medical field to avoid unnecessary notifications which will only be ignored.

- The diagnostic process. The doctor have several conditions in mind, but tries to eliminate the statistically most common and dangerous first. Trying to narrow down the alternatives until the doctor is quite certain about the medical condition of the patient.

3.3 Workshop

The 22nd of February 2019 we had a workshop. The purpose of the workshop was to

- Identify components in the treatment plan of asthma patients.

- Identify difficulty levels, and how the questions will be more detailed for every difficulty level.

- Make a learning map.

The antecedences for the meeting was

- Professor in computer science Yngve Lamo. Background in model driven engineering and health informatics.
- Assistant professor in computer science Svein Ivar Lillehaug. Background as a researcher in health informatics.
- Postdoctoral fellow Fazle Rabbi. Background in model driven engineering.
- Medical doctor and PhD student in health informatics Job Nyangena.
- PhD research fellow in interaction design Rosaline Barendregt. Has written a master thesis in gamification.
- PhD candidate in computer science and health informatics Suresh Kumar Mukhiya.
- Master degree student in computer science Ben-Richard Ebbesvik.

Figure 3.1: Anticlockwise from front left: Yngve Lamo, Rosaline Barendregt, Suresh Kumar Mukhiya, Svein Ivar Lillehaug, Fazle Rabbi and Job Nyangena

The meeting started with Ben-Richard informing the status of the project by doing a cognitive walk-through and a demonstration of the application.

Yngve presented ideas for further development of the application. The important thing, was the concept of splitting up the questions in themes which relates to components in the treatment plan. Job helped identify these themes as assessment, diagnosis, management and treatment.Further we identified what type of questions we wanted to ask, and how they fits into different difficulty levels, based on the details of the questions. We ask factual questions for level 1. We use scenarios in level 2, where we apply facts and the detail level is categories. I.e. what class of medication should be administered to the patient. In level

3 we continue with scenarios, but here we ask for much more details, like the dosage of a medication or how often it should be administered.

When playing level 1 the student should get questions from all themes in level 1. When the student completes level 1, the student should no longer get questions from that theme. This is to avoid boring the user by repeating the questions the student already knows the answer of. He should only get questions from themes he struggles with. I.e. on the first run level 1, the user gets every question in assessment right, but have some mistakes with diagnosis and management. Then on the next run, he only gets questions from level 1 diagnosis and management. This continues until he has reached the passing condition on every theme in level 1.

We further identified a dependency in the treatment plan. To be able to do a follow-up, the students first needs to know something about assessment, diagnosis and management of the patient. The follow-up is actually an evaluation of the treatment which have been given, based on the suggested diagnosis. The evaluation will tell how the patient responded to the treatment, and we need the student needs to take actions whether the patient responded or his condition became better or worse. When we have such a dependency, the student needs to complete assessment, diagnosis and management before follow-up gets unlocked. Since follow-up is only relevant in a situation where there has already been set a diagnosis and given a treatment, the follow-up is only part of level 2 and 3, where the questions are given as scenarios.

To complete a level, all passing conditions at that level in each theme have to be met. When the student qualifies for a new level, he only gets questions from the level he plays. The same concept of only getting questions from the themes at that level you haven't met the passing condition, continues for level 2 and 3.

We planned to have a visualization of the passing condition in the application. The passing condition will be shown in a chart in the summary section after each game. The passing condition will be marked as a line over every theme for the level the student plays. The students scores for each theme at that level be shown as bars. When a bar reaches the line, a passing condition is met.

Figure 3.2: Assessment and diagnosis are components in the treatment plan. In the learning map they are themes. Under each theme there are difficulty levels. Questions for each level are written on post-it notes.

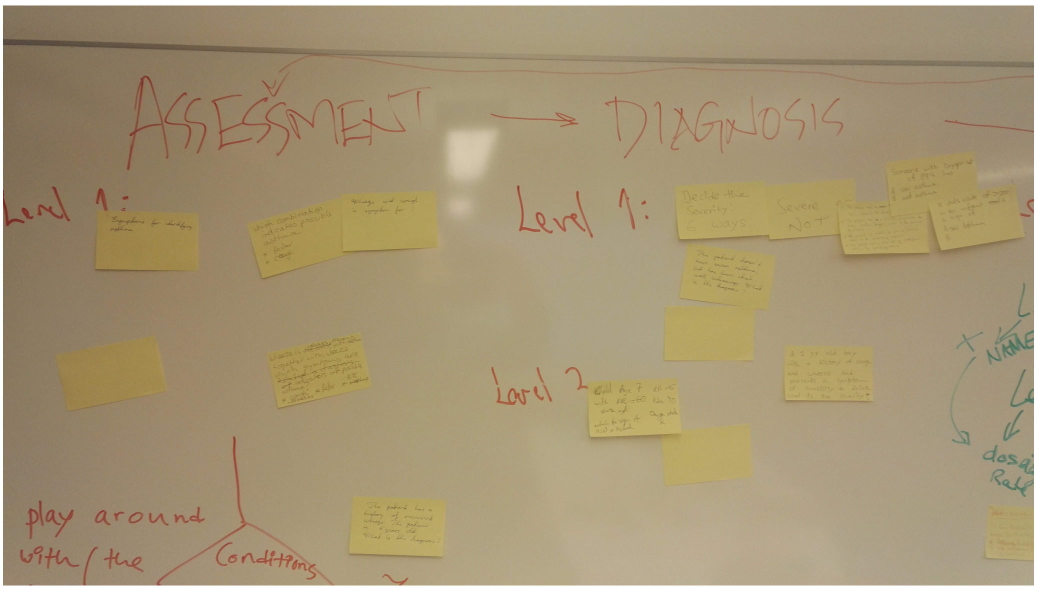


Figure 3.3: Management and follow-up are components in the treatment plan. In the learning map they are themes. Under each theme there are difficulty levels. Questions for each level are written on post-it notes.

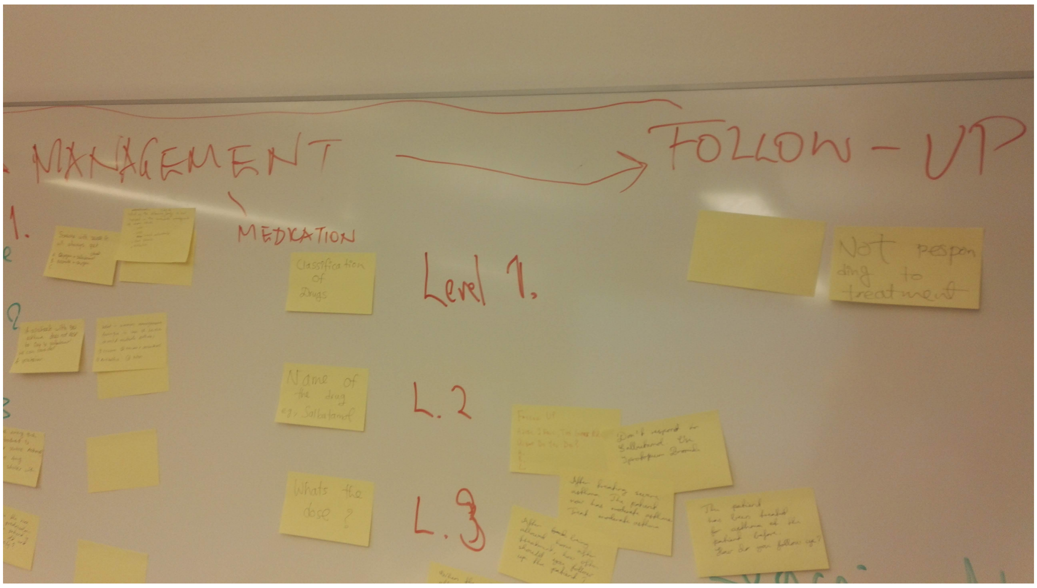
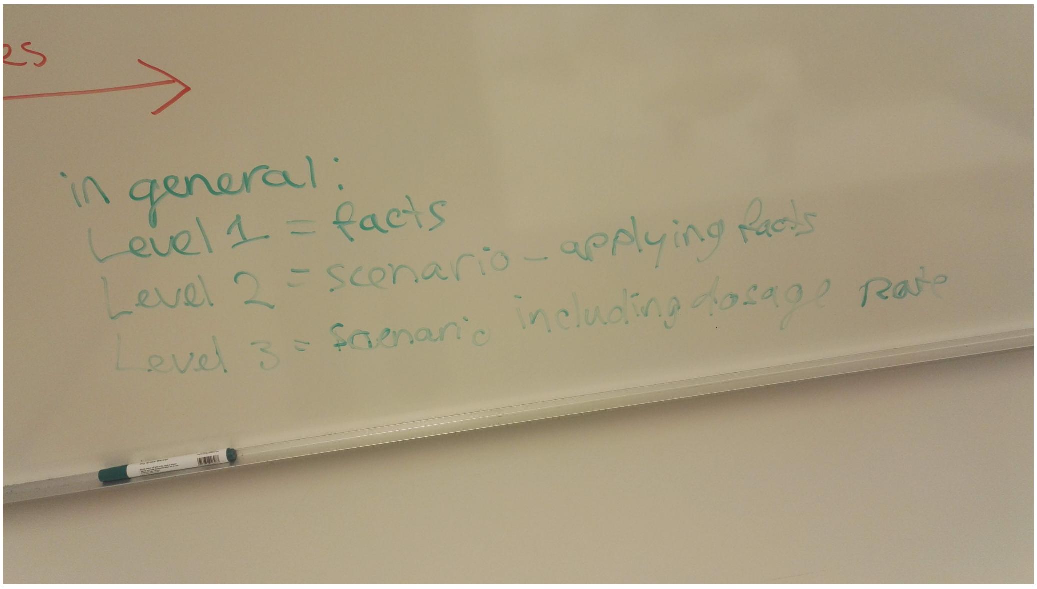


Figure 3.4: What type of questions the student will get at each level.



Job continued the meeting by talking about the guidelines.The paediatric guideline of asthma is called "possible asthma". That is because in an emergency situation asthma is the most dangerous airway condition and can be lethal. If the patient shows signs of asthma, he will be treated for asthma to reduce risks of an unwanted scenario.

We identified users of the application:

- Formal training, where last year students are reading for their exams.
- Anyone can learn, so it can be used to inform and educate the public.
- In countries such as Kenya, where there are a large deficit in doctors and nurses, sometimes nurses has to work as doctors. Or community workers need to take the

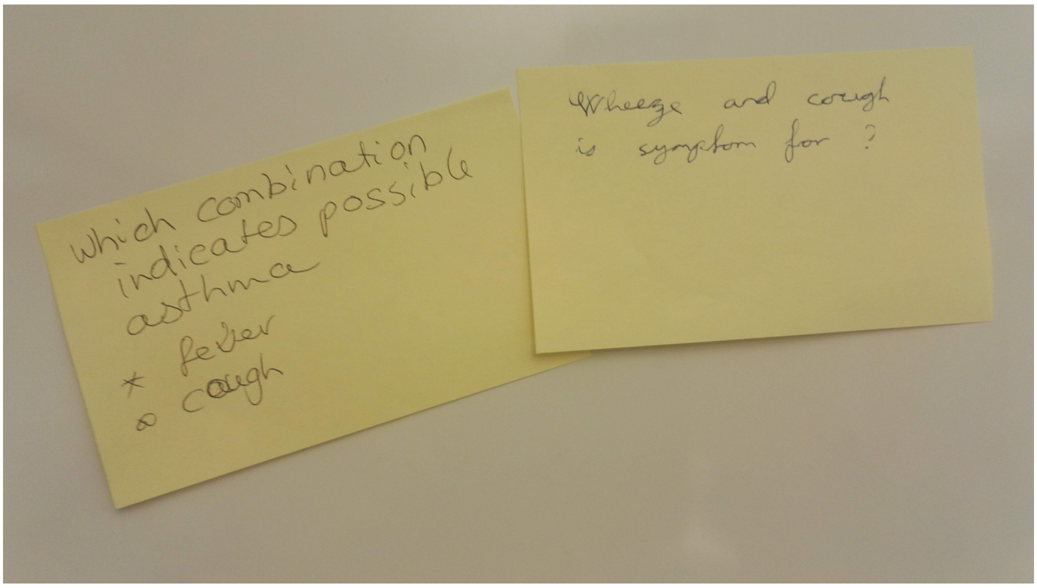
role as doctor or nurse. The application will help educating nurses and community workers for such scenarios.

There was also talked about how the situation in medical training is for the student. When a patient comes to the emergency room with severe asthma, the medical doctors will have all their focus on that particular patient. The medical student will typically not take part in the assessment, diagnosis or the initial treatment of the patient. The medical student will typically only take part in the monitoring, evaluation and follow-up of the patient, when the situation is less critical. The application will give the medical student an alternative way to train in assessment, diagnosis and initial treatment of a made-up patient with severe asthma.

Job continued the workshop by going through the Kenyan paediatric guideline of possible asthma Republic of Kenya 2016. This is the guideline we will base our quiz on. Job answered questions from the group about details of the guideline. It is important to understand the general flow as well as the details to be able to make good questions for the quiz. The guidelines is poorly written in terms of wrong use of sentential operators. These mistakes needed to be clarified.

The rest of the workshop was for the participants brainstorming around the questions which will be used in the quiz. Each participant wrote questions on post-it notes, and placed them at a suiting level and theme on the blackboard. At the end, Job went through the questions and we had a small discussion around the suggested questions. We managed to produce question templates to be used in asthma quiz of the application.

Figure 3.5: Suggestions for questions were written on post-it notes and attached to a difficulty level under a theme on the black board.



Chapter 4

Developing a learning tool for health workers

4.1 Extracting knowledge from the clinical practice guidelines

4.2 Data models

4.2.1 DPF metamodeling

4.2.2 Entity model

4.2.3 Workflow model

4.2.4 Game model

4.3 Game engine

The game engine is based on some of the concepts presented in the article of Eide, Kristensen, and Lamo (2008).

Eide, Kristensen, and Lamo (2008) presents a dynamic content management system (DCM) made for e-learning. In DCM the focus is on removing the tight coupling between the learning material and the teaching course. By analysing the learning material and course, they can define conceptual atomic units of knowledge which they put into a knowledge repository. From this repository they may draw knowledge elements and organize into the hierarchy of a course. To model a course they use concept maps, which are directed graphs, where the vertices are concept labels and edges indicates the relationships between vertices. DCM operates with three concept maps: knowledge map, learning map and student map. The knowledge map is used to model the entire content of the knowledge repository and the hierarchy structure of a course. A learning map is used to model a specific course and is a representation of the learning process. The content units (vertices) in the knowledge map gets expanded, and becomes evaluation and resource vertices in the learning map. Content units from the knowledge map can be omitted if they are not needed in the specific course. The student map representing the progress of a specific student taking a specific course. The edges shows which resources he has used, the evaluations and in which order.

Translated to our project, a course will be the paediatric possible asthma guideline (Republic of Kenya 2016).

we try to decouple the learning material from the presentation or course. In our specific case, the presentation is the flow-chart of the paediatric possible asthma guideline (Republic of Kenya 2016), and the learning material is its content. The learning material gets divided into atomic units called

The basic requirement for DCM is that we have a repository of knowledge elements. We can draw knowledge elements from this repository, organize them into a hierarchically structure

As each question in a quiz are related to a certain component in the treatment plan or theme in the learning map, the student will be measured how well he performs on each of these themes. For the asthma guideline (Republic of Kenya 2016), we have identified four themes. Assessment where the student will be tested in the initial examination. Diagnosis, where the student will determine a diagnosis as well as the severity. Management, where the student will determine which actions should be done to treat and best give the best care to the patient. The last discipline is the follow-up, where the student will be tested in evaluating the treatment, give advise to and educate patient and caregivers, provide the right medication and regular follow-up.

By splitting up the score in themes, the student can easily see which areas he is strong and where he needs more training.

We can also adapt the questions in each discipline to the student's level. If the student has proven to be very good in providing the right amount of medicine to asthma patient, we can provide more difficult questions to challenge the student some more. If he struggles at setting the right diagnose, we can provide more basic questions to strengthen the students basic knowledge.

The disciplines should be automatically picked from the entity (and worflow?) model.

The tree structure of discipline scores. Diagnosis have examination, investigation, setting the severity. Management have advises, medication, admit, surgery and so on.

The student will also be provided with a total score, which will be the average score of each of the disciplines. The student can compare the total score of e.g. the asthma quiz and the jaundice quiz, and see which medical condition he needs to train more on.

4.3.1 Multiple-try feedback

The quiz uses a concept which is called multiple-try feedback (MTC). That means for every question the student gets more than one attempt to get the answer right. A feedback will be given immediately after each answer is submitted. The feedback consists of a message which tells whether the answer is correct or wrong. If the answer is correct, the user will receive "correct" and an explanation of the answer. If the answer is wrong, there will be no hints or explanations than just "incorrect".

Concept	Abbreviation	Feedback after each question	Multiple attempts at each question	Hints on wrong answer
No or delayed Feedback	NF or DF	No	No	No
Knowledge of Correct Response	KCR	Yes	No	No
Multiple-Try feedback with knowledge of Correct response	MTC	Yes	Yes	No
Multiple-Try feedback with Hints	MTH	Yes	Yes	Yes

The point of doing MTC, is to make the student think over what was wrong with his first answer. Did the student misinterpreter the question? Was there a detail he missed? Does the student lack the knowledge or was he just sloppy in his first attempt?

Clariana and Koul (2006) did a study where they divided 82 students into five groups. DF-, KCR, MTC and two control groups. The first control group got a text and a question at the end. The second control group got a text, but there were no question given. After 5 days,post-test was held to see what the students had learned and remembered. The post-test questions were either identical to the questions in the learning material, transposed where the order of the stem of the question and the correct-response gets reversed, paraphrased where post-test questions had the identical content as the learning material, but the phrasing was different and used different words, and a combination of transpose and paraphrasing. The results showed that DF and KCR groups performed better on identical, transposed and paraphrased-transposed questions. MTC performed better on paraphrased questions. The conclusion was that DF and KCR was much better methods for remembering the learning material word for word, but MTC was better when you have to think and reason about what you have learned.

Attali (2015) further did a did a study on NF, KCR, MTC and MTH using open ended and multiple choice questions on mathematical problems. They showed that solving an open ended question rather than multiple choice was a more efficient way to learn. The learning outcome was the same for the students using NF and KCR. However the learning transfer was greater when using multiple-try (MTC), and even more so when getting a hint on incorrect answer (MTH). They explained the results effortfull and mindful problem solving. In a multiple-try feedback, the user will have to reflect on their errors, re-evaluate the problem and understand the initial error. An open ended question will also require more effort of the student, as they have to generate a an answer rather than selecting from alternatives. On the combination of multiple-try and multiple-choice, it was suggested that some users might be less likely to review their incorrect answer and mindlessly clicking on another alternative.

According to Morrison et al. (1995), students which perform badly on answer until correct questions, will often become frustrated, loose interest for reviewing the material and probably depress learning.

As thinking and reasoning about a diagnosis, treatment plan, evaluation and follow-up of a treatment is part of a medical procedure, we believe that multiple-try feedback is the right approach. Because of the nature of a mobile app, where gestures are more convenient than typing sentences, multiple-choice seems to be the right choice even, though open ended questions has proven better results in. There's also a technical problem with evaluating free typed sentences.

Some of the questions in the app are too simple for a hint to be meaningful.Example: "the symptoms for asthma is" and the answer can be "cough and wheeze". Where hinting "cough", would be giving away the answer, especially in a multiple-choice format. However, the data model supports hints as links to external learning material. E.g. the student could look for the answer in the guideline itself.

We solved the "answer until correct"-problem described by Morrison et al. (1995), by having a "read more" button displayed upon incorrect answer. The "read more"-button will display the correct answer, an explanation and continue to the next question. Avoiding the user becoming frustrated and discouraged by having to brute-force the answer keys to progress.

4.3.2 Reward system

By having multiple-try feedback, another problem rises, and that is the reward system. If there is no penalty for incorrect answers, a student which needs ten attempts per questions, will get the same score as a student which answers all the questions correctly on the first attempt.

Attali (2015) solved the problem by giving 1 point for answering correctly on the first attempt. 2/3 points for the second attempt, 1/3 for the third and 0 points if the third attempt was incorrect. A limitation with this method is that it makes no sense for the student to make more than three attempts. Morrison et al. (1995) had another strategy where they adjust the scores by dividing the total score by the total number of attempts during the quiz. A consequence is that attempt number two will have a huge penalty which is halving the students total score. While attempt number twenty will give a very small penalty from attempt nineteen. A method to dampen this effect could be dividing the total score by the sum of reviews and number of questions.

The solution we used was having a fixed value for every answer alternative. The quiz author chooses the penalty for each distraction and reward for each answer key. The idea is that the distractions can have some sort of degree of wrong or right, and this can be reflected in the scoring. On the question "what are the symptoms of asthma?", "difficulty breathing" is a more correct answer than "fever", as "difficulty breathing" is a symptom of asthma in combination with wheeze. Fever is not an asthma symptom at all. In future work, the penalties can be automated as you can see from the entity model whether the symptom belongs to the asthma guideline or not. A distraction from respiratory disorders may give a larger penalty than a distraction from the asthma guideline, but smaller penalty than symptoms not belonging to respiratory diseases.

Both Attali (2015) and Morrison et al. (1995) avoids the scenario where the user gets a total minus score. This may be a strength of these methods, as a negative total score seems like a very harsh feedback and might demotivate the student. In our solution we use negative numbers as penalties on distractions, such that a negative total score may happen. We try to limit the likelihood of a negative score by providing a very reward for a correct answer and a very small penalty for a distraction. Typically the reward is 10 points and the penalty -1 og -2 points. The intention is to encourage the student to review the incorrect answer and try again. As the format is multiple-choice and the penalty-reward ratio, there is a little risk involved trying multiple times. But giving up by clicking "learn more", the student will not get an additional penalty, but will miss out on the reward. By clicking answer alternatives mindlessly and consequently clicking "learn more" will probably not end up in a negative score, but is more likely to end up in a negative score than mindlessly click answer alternatives until correct.

A solution to having a not very strict game, encouraging to playing and learning, one can also have a very strict examination version. The idea is that after examination, the results will be sent to the lecturer (or a governing body of some kind) to evaluate what the overall knowledge of the students, as well as details of what the students are really good in and where do they struggle. The lecturer can then target the weak of points of the students in one of the next lectures.

4.3.3 Constructing narratives and answer keys

4.3.4 Open world, closed world assumption

Rabbi Fazle has written about this. What do we do if central cyanosis is not in the patient model? According to closed world assumption he then doesn't have central cyanosis. In the open world assumption, we simply don't know when it's not in the model. In MDE, closed world assumption is the standard way og solving this problem. In our application open world assymption is probably a more correct solution. If central cyanosis is not in the model, we should simply do an examination and confirm that the patient doesn't have that symptom.

4.3.5 Unlocking harder levels at a certain category

(somewhere in the paper I need to refer to Eides, Kristensens and Lamos paper, and discuss the knowledge, learning and student maps and that they need to prove basic knowledge in some disciplines before they can unlock content in other disciplines.)

4.3.6 Visualization of game statistics

4.3.7 Automatically generating new questions

4.4 The mobile application

- React
- React-Native
- React-Native-Navigation (Wix)
- Redux
- React-Redux
- Redux-Thunk
- Highcharts
- Jest

4.4.1 React-Native and Redux

4.4.2 User interface and flow of the user interaction

4.5 Architecture of the whole system

4.5.1 Visualization

4.6 Evaluation

Chapter 5

Discussion

5.1 Research questions

5.2 Limitations of the model

- Can't ask questions like "what are the symptoms for severe asthma?"
- Difficult to ask what NOT to do. If the vertex doesn't exist, only an empty string gets returned. Can only be used were we actually have written "don't admit to the hospital" as an example with hospitalization.
- The inheritance makes it difficult to generalize some questions. We can't make a template which asks about the Rate a medicine should be taken with. We need to specifically ask for that medicine. To be able to ask for a general medicine, one solution can be to introduce a new tag which compares the substring of the type of the vertex. Another solution is to use the meta model and not the instance model. We don't use inheritance on diagnosis because of this.
- To avoid the problem described in the previous point, we don't use inheritance on Diagnosis. A limitation here is that a patient can only have one diagnosis.

5.3 Observations

5.4 Challenges

5.5 Reflection

Chapter 6

Conclusions

6.1 Further research and development

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