Model-driven Automatic Question Generation for a Gamified Clinical Guideline Training System*

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Abstract. Clinical practice guidelines (CPGs) are a cornerstone of modern medical practice since they summarize the vast medical literature and provide care recommendations based on the current best evidence. However, there are barriers to CPG utilization such as lack of awareness and lack of familiarity of the CPGs by clinicians due to ineffective CPG dissemination and implementation. This calls for research into effective and scalable CPG dissemination strategies that will improve CPG awareness and familiarity. We describe a model-driven approach to design and develop a gamified e-learning system for clinical guidelines where the training questions are generated automatically. We also present the prototype developed using this approach. We use models for different aspects of the system, an entity model for the clinical domain, a workflow model for the clinical processes and a game engine to generate and manage the training sessions. We employ gamification to increase user motivation and engagement in the training of guideline content. We conducted a limited formative evaluation of the prototype system and the users agreed that the system would be a useful addition to their training. Our proposed approach is flexible and adaptive as it allows for easy updates of the guidelines, integration with different device interfaces and representation of any guideline.

Keywords: Clinical Practice Guidelines · Model Driven Engineering · Gamification

1 Introduction

The rate at which medical knowledge is produced is accelerating and it is estimated that in 2020, the doubling rate of medical knowledge will be 73 days down from 7 years in 1980 [9]. At this rate it is virtually impossible for clinicians to keep up with new knowledge [14]. Clinical practice guidelines (CPGs) provide a promising solution to this problem. CPGs are systematically developed statements that assist practitioners and patients to make decisions about appropriate health care for specific circumstances [21]. They are a comprehensive summary of the available evidence about medical conditions

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and provide recommendations for the management of those conditions [15]. 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 [37]. The mere availability of guidelines does not necessarily mean that the recommendations will be used in actual care. Indeed, there has been a reported gap between recommended care according to the evidence base and actual practice leading to preventable errors in practice [12, 2]. This gap can be attributed to several barriers to guideline dissemination and implementation which include: internal barriers (lack of awareness, lack of familiarity, lack of agreement with the guideline content, and the inability to overcome the inertia of previous practice) and external barriers (i.e., patient, environmental, and guideline related factors such as ease of use and complexity of the guideline) [7].

The nature of guideline development means that published guidelines are well-researched, comprehensive documents that can be prohibitively voluminous. For example, the National Heart, Lung, and Blood Institute (NHLBI) 2007 Guidelines for the Diagnosis and Management of Asthma full report is 440 pages long [24] while the National Institute for Health and Care Excellence (NICE) guidelines for the diagnosis monitoring and management of chronic asthma (2017) report is 39 pages long [25]. Such large texts are impractical for use at the point of care. Additionally, poor guideline presentation has been identified as a factor in the lack of physician familiarity as some of the guidelines have been described as being tedious, repetitive, confusing, and unclear [6].

To mitigate some of the barriers to knowledge acquisition of guideline content, new dissemination strategies aimed at improving awareness and familiarity of guideline content are required. Active guideline dissemination strategies have been found to be more effective than passive strategies at improving the application of evidence based recommendations in patient care [16]. In particular, educational interventions (e.g. distribution of printed guidelines, educational meetings and outreaches) strengthen the effect of clinical educational material. Further, the more intensely the information is provided through these interventions, the greater its effect on the recipients [23]. Research into active strategies for clinical guideline dissemination are timely and relevant as they will potentially help to plug the gap between recommended and actual clinical practice.

One potentially useful active educational intervention is in the distribution of gamified guidelines. Gamification is the use of game design elements in non-game contexts [11, 10]. It uses game based mechanics, aesthetics and thinking to engage people, motivate action, promote learning and solve problems [18]. The concept of Gamification is relatively new and has been used to describe the use of game-based concepts and techniques, with the goal of increasing the motivation and engagement of the participants and improving the results.

The implementation of guideline summaries as interactive, gamified flowcharts on a mobile platform will potentially mitigate the problems of guideline complexity and presentation that plague the effective dissemination of guideline content. In this paper we present a formal model driven approach to gamification of clinical practical guidelines. To illustrate the approach, we present three models, an entity model of the clinical encounter domain, a workflow model for the clinical processes and a game model all of which will be integrated to create our gamified system. We then describe a prototype mobile-based guideline app that incorporates these models to present a gamified interactive guideline training tool. Finally we conduct a limited formative evaluation of the prototype to get user feedback that will inform future improvements of the system. This paper extends the work presented in an earlier paper by Nyameino et al [26]. In this extended version we elaborate on MDE concepts being used in the development of domain models for gamification, we present an evaluation of our approach and a discussion on its implications. Finally we present a revised related work section where we compare our work with existing automated elearning and gamification approaches. The results indicate the potential of our approach in developing e-learning tools with MDE techniques.

2 Method

2.1 Diagram Predicate Framework (DPF)

In this work we use a formal diagrammatic approach to model driven software engineering (MDE), called Diagram Predicate Framework (DPF) [35]. DPF formalizes software development activities such as metamodelling [35] and model transformations [36]. It is based on category theory [3] and graph transformations [22]. We can use DPF to formalize clinical guidelines in the form of diagrammatic specifications of clinical domain models at different abstraction levels . The diagrammatic nature of DPF also facilitates visual representations of guidelines that can be presented at different level of abstraction. A model in DPF is represented by a diagrammatic specification $\mathfrak{S} = (\mathcal{S}, C^{\mathfrak{S}} : \Sigma)$ which consists of a graph $\mathcal{S}$ and a set of constraints $C^{\mathfrak{S}}$ specified by a predicate signature Σ.

The predicate signature is composed of a collection of predicates, each having a name and an arity (shape graph). A constraint consists of a predicate from the signature together with a binding to the subgraph of the models In order to apply DPF for the modeling of a gamified training system that operates over clinical practice guidelines we need to formalize the concepts of a guideline using DPF and also model the gamification concepts with DPF.

2.2 Model Driven Engineering

Model Driven Engineering (MDE) is a system development paradigm that promotes the use of models as the primary artefacts that drives the whole development process. In MDE models are specified using a modelling language whose syntax and semantics are defined by a metamodel [38]. This allows for the development of domain-specific modelling languages (DSLs) using notations and abstractions that are unique to a given domain. The use of DSLs allows for the development of more expressive models and ease of use by domain experts. A metamodel architecture introduces a generic pattern of metamodeling hierarchy in which models at each level are specified by a modeling language at the level above and conform to the corresponding metamodel of the language. Figure 1 illustrates a metamodeling hierarchy where a model M_i at a certain

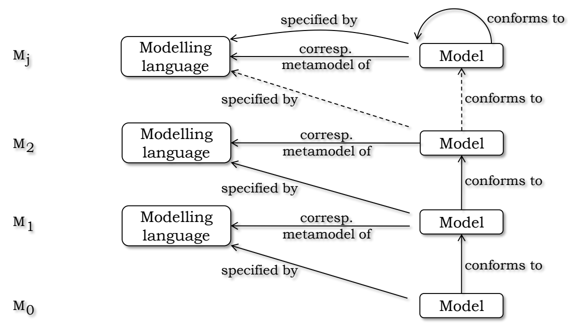

Fig. 1. Generic pattern: modeling languages and metamodels [34]

level i conforms to a metamodel M_{i+1} at the level above until a model M_j has itself as metamodel, called a *reflexive model*

According to the traditional metamodeling architecture, proposed by OMG, a metamodeling architecture is organized in 4 meta-levels $M_0 - M_3$, known as the Object Management Group (OMG) 4-layered hierarchy [5]. A possible interpretation of the hierarchy is summarized as follows:

- The bottom layer M_0 is called the user object layer and it contains the data of the application (e.g. the instances populating an object- oriented system at run-time).
- The M_1 layer contains models (e.g. a UML class diagram of a software system).
- The M_2 layer contains metamodels that captures the language (e.g. UML class diagrams or statechart diagrams).
- The M_3 layer is the meta-meta layer that contains the meta-metamodel MOF. This layer describes the properties of all metamodels.

In the next few paragraphs we are going to describe the different models we propose to use. First an entity model for the clinical encounter domain, a workflow model, a game model and an integrated multi-metamodel that incorporates the entity and CPG workflow models.

Entity model In Figure 2 we present an entity model from the clinical domain. The model contains the main entities in the clinical domain, their attributes and the relationships between them. This is illustrated in Figure 2 where we have entities such as *Patient* with the attributes *name*, *age* and *weight* and corresponding relationships with other entities such as *Patient* ***undergoes*** *Investigation* and ***receives*** *Treatment*.

Workflow model Clinical practice guidelines are often summarized in algorithmic workflows showing the flow of management. Workflow models may be used to represent the flow and corresponding branching conditions of a clinical guideline In Figure 3 we present an example metamodel (M_2) for behavioural models which specifies that instances of Task can be connected by Flow edges. On the next abstraction level (M_1) we see a generic treatment model that is typed by the elements from metamodel M_2.

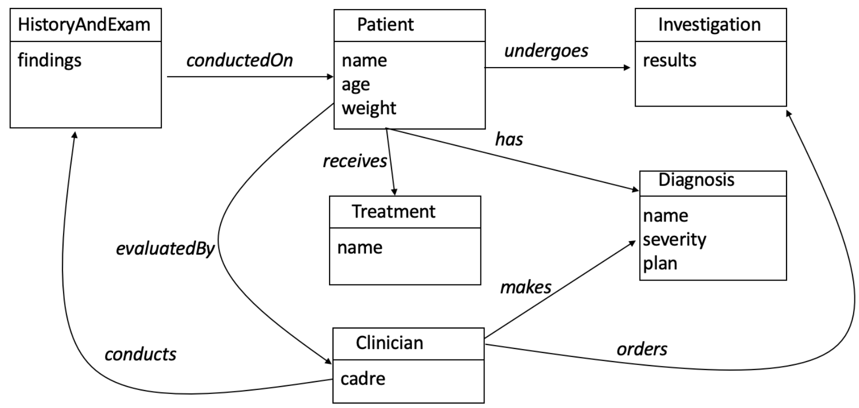

Fig. 2. A simplified entity model of the clinical encounter domain

The treatment model has three tasks Assessment and Diagnosis, Treatment and Evaluation. Finally, at (M_0) we see an instance of the treatment workflow of a severe asthma diagnosis.

Game model Games are goal-oriented activities with reward and progress tracking mechanisms. These core gamification concepts should be under consideration in the design of gamified e-learning systems. In our system, a game engine will automatically generate questions from the entity and workflow models to instantiate a training module. The questions are categorized according to the learners skill level (beginner, intermediate, advanced) and each question has a reward in the form of points. A game model should also specify a learner profile that tracks the learners activities.

Gamification elements The core concepts of games that should inform the design of gamified e-learning systems are goal oriented activities with reward mechanisms and progress tracking [39]. In the training of guideline content, the main goal is for the trainees to learn how to treat different aspects of a disease as described in the guideline. The reward mechanisms and progress tracking aid in increasing the users engagement and motivation [4]. We describe the game elements below.

– **Category:** a guideline is developed for a specific medical condition. The quiz category will be the medical condition for which a guideline has been developed.
– **Level**: This is the difficulty level of the question.
– **Passing condition:** This is the minimum number of points a student needs to score to successfully complete a specific difficulty level and be allowed to move to the next level.
– **Entity Instance**: a pointer to an instance of an entity graph. It is used together with a template to generate text.

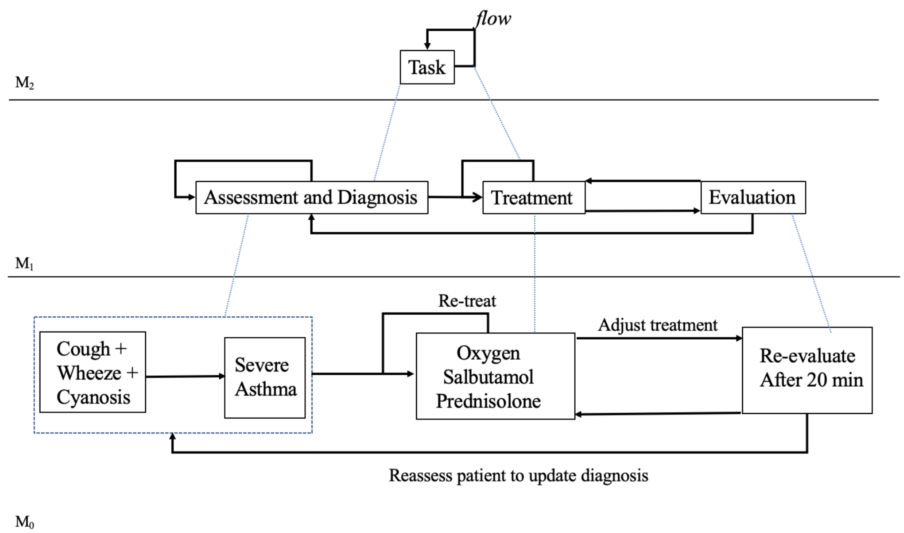

Fig. 3. The workflow model with its metamodel [26]

- **Question:** a pointer to a template model. By using a template model, we can reuse templates on many entity instances.
- **Alternative:** or distraction. It is one of the answer alternatives for a question.
- **Reward:** a reward or penalty is given based on the correctness of the choice chosen by the student. A correct choice is rewarded while a wrong choice is penalised.

Model integration Separation of concern is a potential way to reduce the complexity of software systems. To raise the level of abstraction of complex software systems, we may require to model various aspects of a system in different models. However, to understand the functionality of the system as a whole we need to study the integrated system. One of the major problem of integrating complex information system is the heterogeneity of its subsystems. Requirements for integrating heterogeneous distributed systems are increasing with the rapid technological advancements. The study of integrating heterogeneous system is a complex process consisting of information, expert knowledge management, decision making support. In this paper we study model integration for constructing e-learning modules. The training model is built by the integration of the entity and workflow models based on the principles introduced by Rabbi et al [27]. The states of the training module TM are defined by a set of elements that include a pair of workflow instance WI and an entity instance EI: $TM_i = < EI_i, WI_i >$ where i is a natural number. This integration of models is shown in Figure 4 and the concept is discussed in more details in subsection 2.3. In Figure 4, we show a section of the entity model with values from a given scenario where based on the *History & Examination findings*, a *Diagnosis* of Severe Asthma is made and its *Treatment* specified The flow of how this process should happen is shown in the workflow model.

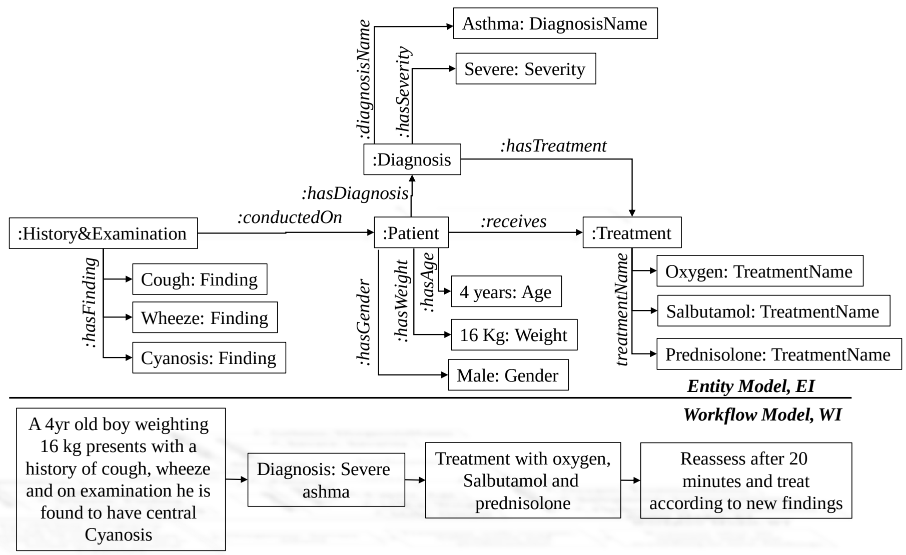

Fig. 4. Integrated entity and workflow models [26]

2.3 Training modules

Rabbi et al presented an approach where different aspects of a system were coordinated by means of multiple metamodels [27, 28]. The approach is based on the foundation of DPF.

In the multi-metamodeling approach, a workflow model is integrated with an entity model by means of metamodel coordination. A workflow metamodel is used to design the flow of a system and an entity metamodel used to design the entities and relationship of a domain. A workflow model can be used to represent an abstraction of a CPG but we need to incorporate the detailed domain knowledge in our modelling. In this paper we exploit the use of the multi-metamodeling approach to represent the domain knowledge of a clinical guideline and the clinical process and apply them to execute a training session. The idea of using the workflow model is to control the flow of the game such that the user is interacting with the right gaming element at the right time.

In this subsection we describe a training module which consist of one or more workflow models and one or more entity models. The states of the training module TM are defined by a set of elements that include a pair of guideline workflow instance and an entity model instance that represents the entities within a domain and relationships between them. Figure 5 illustrates an example of two states TM_1 and TM_2 of a training module. The state TM_1 consists of a set of elements that include a pair of workflow instances and entity instances: $\{< WI_0, EI_0 >, < WI_1, EI_1 >, .. < WI_n, EI_n\}$ where $WI_1, WI_2, ..WI_n$ are workflow instances and $EI_0, EI_1, ..EI_n$ are DPF entity instances. Figure 6 shows a training session flow which consists of a sequence of states of training module i.e., $Training_{Flow1} :=< TM_1, TM_2, ...TM_k >$. In Figure 6 the game engine instantiates a training session by generating questions based on the entity model and the workflow model. For example, it could initially generate a scenario based on the patient details and history and examination findings and ask what the diagnosis is. If answered correctly, it will move on to the next task and ask about the treatment. A training session is composed of a sequence of training modules and is evolved from the initial state of a training flow and progresses based on the answer provided by the user.

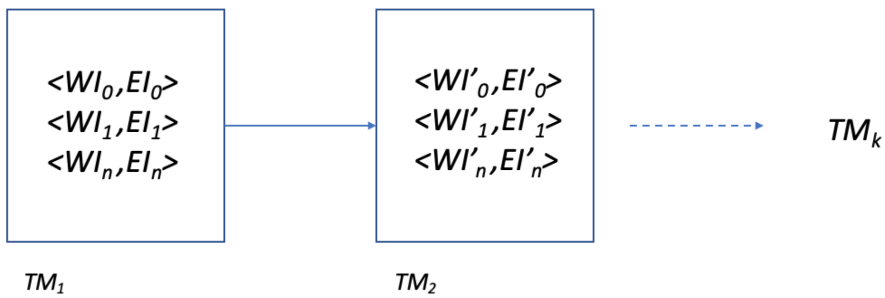

Fig. 5. States of training module [26]

In our approach a training session is evolved from the initial state of a training flow and progresses based on the answer provided by the user. Figure 6 illustrates the idea of the progression of the states of training session. Depending on the answer given by the user, a game engine consults with the training flow and evolves the state of the training session. We use two DPF predicates $< Enabled >$, $< Disabled >$ to represent the current status of the training modules. A training module TM_0 when annotated with the $< Enabled >$ predicate indicates that the training module is currently active and is being considered for training.

2.4 Formative evaluation

Formative evaluations involve evaluating a product or service during development, often iteratively, with the goal of detecting and eliminating usability problems [31].

An evaluation of the application was done with two cadres of clinicians. We recruited two medical doctors and two specialist nurses through purposive sampling to participate in our evaluation. Both of the specialist nurses are employees at the polyclinic for pulmonary diseases at a university hospital in Western Norway. One of the nurses is a specialist in sleep apnea whose masters thesis was on developing clinical guidelines for sleep apnea. The other nurse is a specialist in asthma, but in adult medicine. The two doctors are general practitioners and researchers.

The evaluation methods were a combination of a cognitive walkthrough and a usability test with follow-up questions. Specifically, the nurses were asked to play the

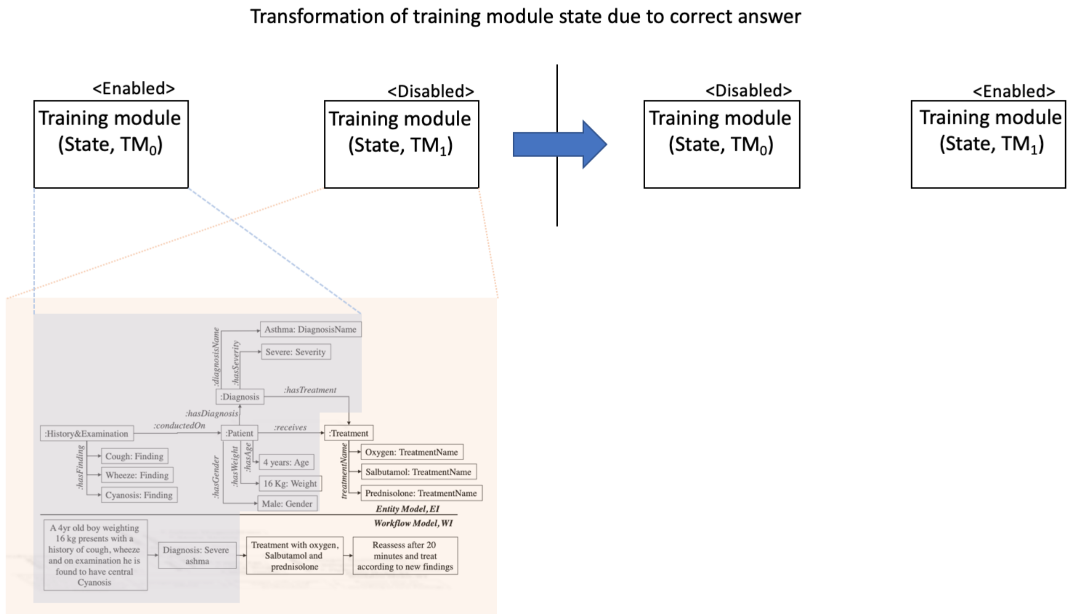

Fig. 6. Progression of the states of training module

most difficult level of the game and to speak out loud on what they were thinking when playing the game and manoeuvring in the application. The two medical doctors were requested to play the entire game, from the easiest level and to completing the most difficult one. By playing all the levels, the doctors would to far greater extent evaluate the learning model.

Discussion points would arise as the clinicians thought out loud. One of the researchers would observe and take notes when problems and confusions occurred, or when the clinician expressed emotions such as joy, excitement or disappointment. After the clinicians had played through the game, the researcher would go through a check-list of topics to discuss. The discussions would be in a semi-structured format, where the check-list worked as a guide. The discussion with the two nurses was done individually, while the discussion with the two doctors was done in a small focus group.

3 Results

3.1 System Architecture

We propose to use a generic architecture based on the idea of multilevel-metamodeling and their coordination. Figure 7 shows an overview of the system. The ‘Game Engine’ controls the training flow, maintains the status of the trainee, produces dialogues and controls the order of the questions The user should be able to interact with the game engine via the presentation layer. We describe the different components of the architecture shown in Figure 7 below.

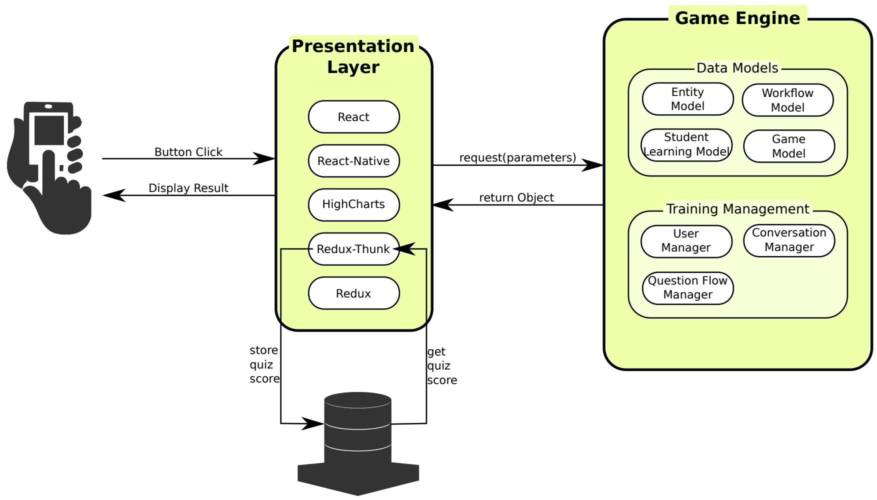

Fig. 7. Overview of the proposed system architecture

Presentation layer: The presentation layer is what the user sees and interacts with when using the application. React Native [30] is a JavaScript framework, used to build cross platform mobile applications for Android, iPhone and UWP. It is based on React [29], where it uses React components to build user interfaces for mobile applications.

For managing the state of the application, we use another JavaScript framework, Redux [32]. It is sort of a repository of functions and variables. When the student clicks on a button in the application, it will trigger a function in the Redux repository. The function can send a request to the Game Engine or do some calculations on its own. Then update a variable in the repository which is connected to a variable in the React Component, and the result is shown on the student's phone.

As the Redux repository is synchronous, we need the framework Redux-Thunk [33] to make asynchronous calls. A student's scores for a quiz is stored in the database on the student's phone. The game engine uses the scores to find questions at the right difficulty level for the student. As database calls are asynchronous, we need Redux-Thunk to make functions which can do asynchronous communication between Redux and the database.

The presentation layer can be implemented in different interfaces such as in a mobile application as in this case or virtual assistants such as Google assistant as in Figure 9.

HighCharts [17] is a JavaScript framework used for making interactive charts. We use it to visualize how well the user performed, and how far he is from advancing to more difficult questions.

Question Flow manager: The question flow manager selects the questions to be asked depending on the level of difficulty of a training session. It maintains the order of questions to be shown to the user. For example, user-A has skill level 1 and chose to go through the beginning session. While randomly selecting questions that falls under the difficulty of 'Beginner', it also looks into the questions that has been used before for user-A. It puts more emphasize on the questions that the user has been struggling with.

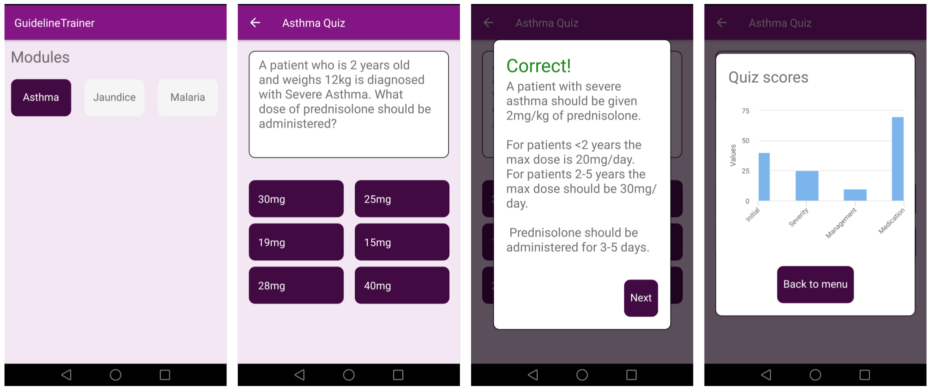

Fig. 8. Flow of the mobile application [26]

Conversation manager: The conversation manager keeps track of the conversation and manages the context of the conversation. For example, if there are three questions to be asked that is related to a child who is 2 years old, then the conversation manager produces a context for three questions and starts the conversation saying "A 2 year old child comes to the emergency department with <some condition>, answer to the following questions:". Afterwards it asks the first question, followed by the 2nd and 3rd questions.

User management: The user management module keeps track of the trainees skill, progress and effort. The user management module is also used to produce visualization showing the performance of a population. If a group of trainee is particularly struggling with a set of questions or question category then the user management module will produce a report and the trainer will be able to monitor it.

3.2 Prototype

Implementation of the mobile application The application is developed using React-Native and JavaScript. React-Native is based on the React framework, and is used to build mobile applications for Android and iPhone. The motivation for using such a framework is reuse of code when supporting both mobile platforms as well as the web.

The game consists of a collection of quizzes, where each quiz contains several questions. These questions are based around a scenario, where the student is presented with answer alternatives. Picking an answer alternative gives the student points for how close he was to the right action. The student is presented with the answer key, an explanation, as well as pointers to the evidence and the relevant guideline for further study.

The quiz conclude with a summary, giving feedback and statistics on students performance. The quiz should have a passing condition to unlock quizzes at a higher difficulty level. This is illustrated in Figure 8.

Question generation To generate questions, the game engine first reads instances of the entity models using a model parser. We then link the parsed model instances with pre-written scenario questions in the form of narrative templates where we use tags to refer to variables in the entity model. The tag refers to a path in the entity graph. The application will traverse through the graph and return the value of the given vertex.

THe game engine then populates the tags with values from the entity model instances thereby creating the question as illustrated below. The correct answer is inferred from the corresponding entity model instance.

```
<%Ben.name%> arrives at the emergency
department.
He <%Ben.hasConsciousness.value.name%>.
```

translates to

```
Ben arrives at the emergency
department.
He is not alert and not verbal,
but responds to pain.
```

Alternate user interfaces As described earlier, the modular architecture allows for the implementation of different user interfaces in the presentation layer of the architecture (see fig 7). This allows flexibility to accommodate the various learning styles of trainees. For example, in Figure 9 we see a sample conversation from the asthma guideline training using Google assistant. We use the google account for registering the participant to our system and we plan to use OAuth 2.0 protocol for authenticating the user from the mobile application to the participants Google account. It will allow the user to switch from one device to another. While the participant is using the mobile application they get more feature such as browsing the guideline.

3.3 Formative evaluation results

As part of the usability evaluation and cognitive walkthroughs, we asked the respondents follow-up questions after they used. We present the responses below.

1. Can the application be a useful learning tool for medical students, nurses and doctors?
   - **Nurse1:** *Very useful indeed. It would be nice to take a test after a lecture about asthma or after having read about asthma to see how much I have learnt and remember. A quiz is far more fun than a check list in paper format. The application is also good for scalability, as you can train a lot of clinicians without adding any resources. Also great if a course leader can see the progress or the level of his students.*
   - **Nurse2:** *Absolutely useful, and I feel I have learnt a lot by just doing this quiz. The nurse found the game to be very engaging, cheering when getting a correct answer.*

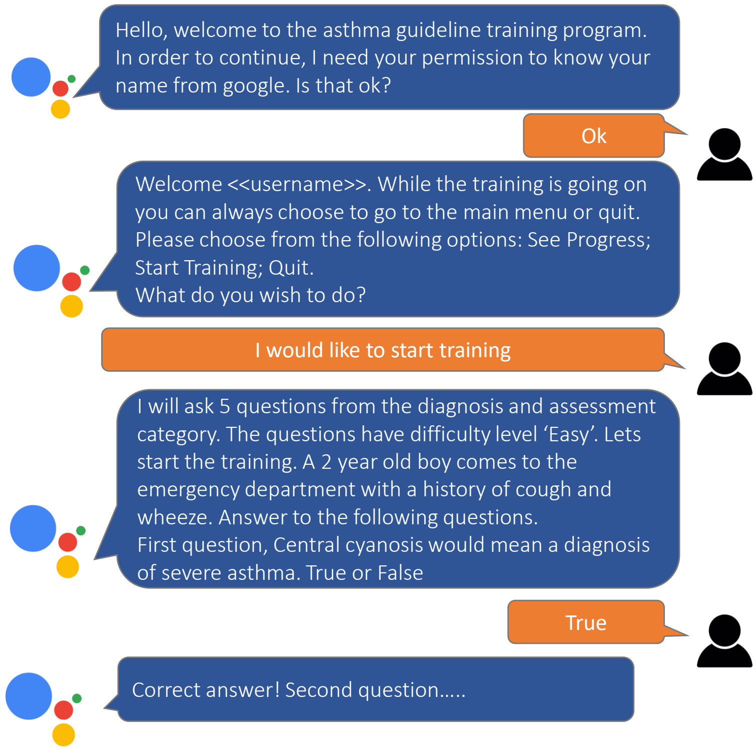

Fig. 9. Sample flow of conversation from the asthma guideline training [26]

  - **Doctors:** *For medical doctors, the quiz will be too basic. For nurses it might be good. For medical students it will be very good, as it fits with how the students works and how they will be tested for exams.*
2. How is the flow of the questions? Is the idea of scenarios where we go from assessment, diagnosis, management and follow-up a good approach?
   - **Nurse1:** *Happy with the flow and the use of scenarios.*
   - **Nurse2:** *Very happy with the flow, being able to follow the patient from the start to the end of the treatment.*
   - **Doctors:** *The categories weren't very clear. The questions are floating into each other. One suggestion is to have oxygen and antibiotic administration as own categories. Then you can measure how well they perform in these categories and ask them to repeat the basics if they perform poorly.*
3. Is the detail level the element to adjust for the difficulties of questions?
   - **Nurse1:** *Yes, but would like to have an even harder level with more details.*
   - **Nurse2:** *Yes, it seems like a right approach. The target group of users is relevant here, that this is meant for the emergency clinic.*
   - Doctors: *Yes, but the detail level of the questions need to be much harder. One example of going to higher detail level could be "what oxygen administration*

device would you initially use to a neonate?" to "administering oxygen using nasal prong to a neonate doesn't work. What do you do?".
In Norway, the patients will visit the hospital with a lot more variation of illnesses and with a higher frequency of less severe diagnoses. Then differential diagnoses gets more important and to represent a lot more clinical conditions as quizzes. The clinicians also work a bit different in Norway. If a patient comes into the hospital with symptoms of severe asthma, they will usually just treat and stabilize the really alarming symptoms and not go through a whole list of treatments.

4. How are the answer key explanations?
   - **Nurse2:** *I like how the measurements corresponds and are calculated with the scenario and the patient they are presented with. The answer key explanations gives relevant answers to the questions asked.*
   - **Doctors:** *The answer key explanations are good. We like that we get an explanation when we answer correctly. We preferred to try until getting the answer correctly rather than clicking "learn more" and proceed to next question. It could be nice to get an explanation why the answer was wrong, but we are rather impatient, we want to proceed and find the correct answer quickly.*

4 Discussion

We have presented a model-driven approach to the design and development of a gamified system for clinical guideline training. We have also conducted a limited formative evaluation to get user feedback on the prototype. Our modular approach provides several advantages. First, it makes it easier to separate concerns and thus updating guidelines requires changes to parts of the entity and workflow models change while the rest of the system remains unchanged. Second, the separation of the game engine from the presentation layer allows for integration with various devices supporting different means of user-interaction.

The user evaluation provided valuable feedback on the system. Overall, the respondents thought that the application was useful to clinical workers especially nurses and medical students as a complement to traditional learning methods. From the respondents, the training tool as it is now generate relatively basic questions and may not be very useful to experienced doctors. Both cadres of respondents (nurses and doctors) agreed that more difficult levels may need to be incorporated into the system to make it more useful.

There are a number of limitations to the gamified elearning system we describe in this work. First, full training of some guideline content requires the learning of some physical skills - such as performing cardiopulmonary resuscitation (CPR). This is a limitation as our system can only train on guideline content that does not require hands on training. Secondly, our system cannot automatically generate the wrong choices (distractors) for the questions and we are currently working on distraction generation strategies to make the system complete.

In the near future, we plan to enhance our conduct a more comprehensive evaluation of the quality of the questions generated by our system. We wil also evaluate the acceptability and effectiveness of the proposed technique as a dissemination strategy for clinical guidelines within resource-limited settings.

5 Related Work

Leo et al presented an ontology based automatic multiple-choice question (MCQ) generation system that exploits classes and existential restrictions to generate case-based questions [20]. Their aim is to develop questions with complex stems that are suitable for scenarios beyond mere knowledge recall. Their system used question templates to generate four types of questions i.e. *What is the most likely diagnosis?*, *What is the drug of choice?*, *What is the most likely clinical finding?* and *What is the differential diagnosis?*. Our narrative templates are more varied and can generate a wider variety of questions .

Farkash et al. presented a model-driven approach to formalize clinical guidelines using natural rule language (NRL) [13]. They specified the constraints of a CPG with an English-like rule language to reduce the gap of the representation and processing of guidelines. The authors presented a set of software components that support the representation, interpretation of CPGs using NRL and that can also be applied directly to a patient's EHR data for analysis. Their approach is supported by a proof-of-concept implementation for a simple essential hypertension guideline directive. Our approach is different with their approach as we use a graph based modeling technique and the main contribution of our approach is to support the training of a guideline by means of gamification .

Kristensen et al. presented a conceptual model for e-learning where the learning materials are divided into atomic units and organized in several graph based models such as 'Knowledge map', 'Learning map' and 'Student map' [19]. These conceptual models provide structure for representing an e-learning environment and an easy-to-use navigation interface for existing learning materials. We adopted concepts from this paper for representing CPGs and game elements by means of Diagram Predicate Framework and multi-metamodelling approach .

In Portugal Del Cura-Gonzalez et al conducted a study to assess the effectiveness of a teaching strategy for the implementation of clinical guidelines using educational games [8]. They presented the findings for the use of an e-learning game EDUCAGUIA to improve knowledge and skills related to clinical decision-making by residents in family medicine. The system consisted of educational games with hypothetical clinical scenarios in a virtual environment. To evaluate the effectiveness of teaching strategies through e-learning, they proposed an average score comparison of hypothetical scenario questionnaires between the EDUCAGUIA intervention group and the control group. Such evaluation is very important and it reflects the usefulness of utilizing games in teaching guidelines. We plan to conduct similar evaluation of our gamification approach with healthcare professionals in future [8].

Aouadi et al used Technology-Enhanced Learning standards to develop serious games which can be used in technological, professional or academic fields for learning. Their goal was to develop a scenario-building approach, built upon a model driven architecture [1]. Their system includes a health course with demonstrative videos and evaluation quizzes with each course having a passing condition. The game is also demonstrated as a 3D game in a context of medical training. In their approach, they used a platform independent model for the development of game components which was transformed into a platform specific model by means of ATL transformation. While their approach is very close to our proposed method, they lack modularization and separation of concerns. In our approach we not only apply multilevel metamodelling but also the integration of different modeling hierarchies which allows us to conveniently articulate various aspects of an e-learning system.

6 Conclusion

In this work, we have presented a model-driven approach to the design and development of a gamified system for clinical guideline training. We also present a prototype mobile gamified e-learning system that utilized our design approach in its development. Finally we present the findings of a limited formative evaluation of the prototype system which received a good response from the users as being useful and scalable. We plan to incorporate the user feedback to improve the system and subject it to further more comprehensive evaluations.

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