Design and Management of an Objective Structured Clinical Examination using the SIMUportfolio Platform

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Abstract: An objective structured clinical examination (OSCE) is a modern and effective way of examination and evaluation of students in terms of clinical practice. Despite its high demands as regards both staff and time, it is certainly worthwhile to test students' skills in this way, and the Faculty of Medicine of the Masaryk University is currently aiming to introduce this modern examination method. Apart from a proper training of employees responsible for the preparation and the process itself of the examinations, much effort has also been made to develop the faculty's own platform which will provide support in various stages of OSCE. The SIMUportfolio is an online platform which, among others, integrates curriculum description, study materials and functions serving to define OSCE stations and examinations, their field evaluation as well as a module summing up the students' results. In this paper, we have described our motivation for the platform development in the context of a simulation centre which is currently under construction, the platform's maintenance and further development. Furthermore, we have presented the finished components of the platform, which have been designed in accordance with processes occurring during an OSCE.

1 INTRODUCTION

Nowadays, with modern information and communications technology (ICT) making it possible to take up new challenges not only in the domain of education of medical and healthcare disciplines, many methodical, pedagogical and technological innovations have emerged. Visionaries and bearers of progressive strategies have been trying – often very systematically and deliberately – to incorporate these elements into the very complicated process of preparation, planning and implementation of the teaching itself. Teaching methods based on scenarios, carried out as problem-based learning (PBL) and team-based learning (TBL), are undoubtedly among the most frequently accepted strategies. In fact, the employment of virtual scenarios can significantly facilitate the understanding of various topics contained in a curriculum and connect the study of medicine to verified and functional paradigms from clinical practice (Berman *et al.*, 2016; Core *et al.*, 2016; Rajputh, Rajabalee and Santally, 2019). Apart from the above-mentioned implementation of new pedagogical strategies, we must not forget about tools and methods of students' evaluation. An objective structured clinical examination (OSCE) is the gold standard in the evaluation of complex clinical skills (Harden, 1988). This way of examination, however, is rather time-consuming in terms of both preparation and implementation itself; therefore, authors of this paper considered whether it would be possible to automate steps that accompany an OSCE from its very beginning to the final results. The exploratory question is whether it is possible to make an effective use of available ICT and to design an online solution which would provide an OSCE support to be employed across study programmes of the Faculty of Medicine of the Masaryk University in Brno, Czech Republic.

1.1 Objective Structured Clinical Examination

An objective structured clinical examination (OSCE) is a modern way of evaluation of students of healthcare disciplines, which has been gradually implemented into teaching at the Faculty of Medicine of the Masaryk University, as part of its SIMU

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(Simulation Centre) activities. This way of examination features the following key characteristics:

- **Objectivity** – all students pass through the same stations and the same situations, with the same evaluation criteria.
- **Structuredness** – each station involves a specific task or an unambiguously defined scenario.
- **Focus on Clinical Practice** – students' theoretical knowledge and practical skills are evaluated according to standardised evaluation criteria, which are based either on either examiner's questions or a predetermined correct procedure leading to the solution of a given problem.

An OSCE aims to verify the student's clinical knowledge and skills such as communication, physical examination, performing procedures, interpretation of results etc., and to provide an objective and specific feedback to students. The introduction of this new type of students' evaluation is not a trivial task for us, and we are trying to draw inspiration from well-established systems. Staff responsible for the correct running of OSCE procedures have been trained in cooperation with partner universities. We have made a concerted effort to follow proven and time-tested procedures (Skrzypek *et al.*, 2017; Świerszcz *et al.*, 2017; Kowalski, Skowron and Nowakowski, 2019).

1.2 SIMUportfolio Integration Platform

The integration platform SIMUportfolio has been developed as an in-house project of the Faculty of Medicine of the Masaryk University. This elaborate and dynamic modular web-based system facilitates orientation in the teaching process for students, teachers as well as the faculty management and, most of all, it is designed to make students' knowledge and skills more effective in clinical practice. Its main objective is to systematically integrate available tools for teaching support, which have been developed at the faculty over the years and currently are among its teaching cornerstones (Komenda and Karolyi, 2019). Experience and knowledge obtained in the solution of national and mainly international research projects became the key aspect to influence the decision to design and to develop our own solution instead of adopting any of the existing ones. The most important of those research projects are Akutne.cz (https://www.akutne.cz/) (Štourač et al., 2013), OPTIMED (https://opti.med.muni.cz/en/) (Komenda et al., 2015), MEDCIN (https://medcin.iba.muni.cz/) (Komenda et al., 2017), MERGER (Komenda et al., 2018), TAME (http://www.tame-project.org/), BCIME (https://www.upjs.sk/en/faculty-of-medicine/bcime/home/) and SIMU (https://www.med.muni.cz/simu/en) (Komenda and Karolyi, 2019).

The entire system is based on curriculum description, which makes it possible to define teaching blocks in a parametric way (study programme, medical discipline, course, learning unit, learning outcome) in accordance with international standards guaranteed by the MedBiquitous association. We have succeeded to transform these standards into a form that can be easily used in a relational persistence layer of the platform, but still can be transformed into the original XML schema (Karolyi et al., 2020). Students and teachers can subsequently use the filled-up database to search for learning units together with their description, keywords, learning outcomes and the form of final examination. The search process in the Czech language has been improved by adding elements of morphological analysis (Karolyi, Ščavnický and Komenda, 2018), leading to more relevant results being provided to users' queries. A direct link between the curriculum and other components is provided by individual modules, which cover specific domains related to the teaching process.

- Teaching activities provide support to guarantors and teachers, with the objective to create scenarios of learning units sequence in a structured way. Depending on the chosen pedagogical method (problem-based learning, team-based learning, flipped classroom), the author is invited to use a form containing obligatory and optional blocks defining how the teaching process should be led. The aim of this process is to harmonise the taught topics regardless of the teacher present on the individual lesson.
- Education portals associate recommended and guaranteed study resources across external platforms that have been used at the faculty. Educational works, multimedia tools, e-learning courses and virtual linear and branched scenarios (virtual patients) can be subsequently easily linked to various building blocks of the curriculum. Students can then easily access all of these materials from a single system.

- Warehouse management will provide well-arranged records of supply of medical equipment, spare parts and consumables needed to run the simulation centre. Its interconnection with courses, learning units and staffing (teachers, technicians for interactive teaching, suppliers) will provide a detailed overview of teaching costs, the current status of stock and orders.
- The reporting module and the export module process all information stored in the SIMUportfolio database. Apart from the possibility of downloading the data in a machine-processable form, the SIMUportfolio also features an interactive browser which scans through the descriptions of individual study programmes. Users of this module can view data sets by employing various types of graphical outputs and associated filters.
- The OSCE module is intended for the examinations' guarantor to design and to plan all stations, including the allocation of observers, students and standardised patients. OSCEs can be also used at the faculty to carry out formative and summary evaluations.

1.3 ICT Support During OSCEs

Both the preparation and implementation of OSCE require a considerable investment from the faculty, including human resources and technical facilities. The examination itself is always scheduled to be carried out during a whole day, with an exact arrangement of stations and exact times of individual students entering those stations. The process of OSCE preparation is rather complex for a guarantor who is expected to design a given examination with all of its parameters. Therefore, a question comes into consideration whether the SIMUportfolio platform could be used to support and to automate some parts of this process. The suitable candidates are as follows:

- Preparation of the station prototype, which can be repeatedly recycled in several examinations.
- Simple and systematic instructions for observers, simulated patients as well as students, including either printouts or electronic distribution of these instructions.
- Preselection of rooms suitable for OSCEs.
- Planning the sequence of students accessing the examination in order to avoid collisions.
- Automated evaluation of examinations based on students' results at individual stations.
- Archiving the examination results and comparing them according to predefined parameters.

The above-mentioned steps can be carried out systematically, using an online tool. However, it is important to perform all steps methodically, in a way which would secure continuity with the entire concept that is being introduced by the faculty in terms of this new type of examination.

2 METHODS

Initiatives aimed at improvements in teaching by the introduction of new pedagogical methods and modern technologies are appearing with increasing frequency. Making study materials available to students in an electronic form is the cornerstone of such initiatives. Other milestones, however, are more complex and more difficult to achieve. In particular, this might be the description of processes which students and teachers at a given faculty must go through, and which might often considerably complicate either the study or the teaching process. The development of a platform such as the SIMUportfolio requires a long-term and active involvement of all interested parties: faculty management, guarantors, curriculum designers, methodology specialists, teachers and, last but not least, students. The result, in the form of a really complex system, then becomes part of a bigger whole, making a real sense in the environment where it is continually developed and adapted to its purpose.

2.1 Simulation-based Teaching

The Simulation Centre (SIMU) of the Faculty of Medicine of Masaryk University is one of the largest and the most modern simulation centres in Central Europe. SIMU represents a completely unique teaching complex combining theoretical and practical education, where a comprehensive spectrum of simulation teaching methods is covered. The innovation of selected medical study programmes using advanced elements of simulation medicine into regular teaching is the main mission of SIMU. The adoption of methodological, pedagogical and technical background is an essential prerequisite for the following domains: (i) interactive clinical training, (ii) development of study materials, (iii) standardisation of teaching and its continuous evaluation, (iv) implementation of objective structured clinical examination (OSCE) and (v)

integration of modern ICT. SIMU also brings methodologies for preparation, training and implementation of virtual patients in clinical medicine using simulation-based teaching in a form of team-based and problem-based learning paradigms. It helps to change the old-fashioned way of teaching and move the clinical phase of medical education from traditional classroom teaching approaches to active learning using self-directed, personalised and collaborative learning environments (Blažková, Sellner and Štourač, 2017).

2.2 Computerisation of the OSCE Process

The process of preparation, running and evaluation of examinations based on this method is very complex. The preparation itself consists of several steps that might be iterative. Running must be effective and as little as possible time-consuming for the OSCE guarantor (i.e. the person planning the agenda, managing the technical team and overseeing the smooth running), for the teacher (i.e. an expert preparing the scenario for a given station and acting as the observer/evaluator) and for students themselves. For these reasons, a web-based platform seems to be an ideal solution, providing available functionalities online. The resulting evaluation of a student is compiled from evaluations from all stations attended by that student. When designing the web-based tool, we considered the following stages:

1. Creating a station, including the allocation of a room as well as the assignment of observers, simulated patients and students.
2. Carrying out the examination itself, with evaluation recorded online into predefined forms in real time.
3. Evaluation and analysis of results according to stations attended by students, with the aim to provide an instant feedback to students, observers and the OSCE guarantor.

2.2.1 Identifying Roles During OSCE

In the entire life cycle of a specific evaluation via OSCE, there are various roles with various rights and competencies. These roles involve a designer, an observer, a guarantor and, of course, a student.

- An **OSCE designer** is responsible for the preparation of scenario at an OSCE station, which should be clearly linked to a selected part of the curriculum (a course, a learning unit and learning outcomes). A teacher actively involved in the teaching process usually finds himself/herself in this role.
- An **OSCE observer** is responsible for the running and evaluation of the examination itself. During the examination, he/she observes the student ' s reactions and records their correctness into the platform, making it possible for the examination to be evaluated later. This role might be assigned to a teacher, a physician or a specialist trained in this activity. Each station at an OSCE requires at least one observer.
- An **OSCE guarantor** oversees the entire process of design, planning and evaluation. This person can also monitor the whole process thanks to an adapted view in the SIMUportfolio platform, which involves up-to-date information on the progress of students going through individual stations, their results and time schedule of the entire examination. This responsibility is assigned to a specific person by the faculty management. An OSCE guarantor must be well acquainted with all OSCE issues, whereas the faculty management must carefully consider the capacities of its staff.
- **Students** themselves are essential for the examination, aiming to prove their knowledge of medical procedures in specific situations. These pieces of knowledge are thoroughly tested at individual stations, and performance at a predefined level must be demonstrated by students at each of them, if they are to pass the entire examination. Point limits must be set in a way which reflects the importance, significance and difficulty of each station in the context of the entire examination.

2.2.2 Stages of an OSCE

An OSCE itself can be divided into three main stages. The structure of these stages is more complicated and can be further divided into partial stages.

The first stage is purely preparatory. The responsible persons (OSCE designers) create station prototypes or use already existing stations. Based on these, an examination with planned stations in a specific location and with a clearly defined sequence of stations is subsequently created. The examination date and start, together with the length of pauses between student groups, are determined. Last but not least, a set of students to be examined during an OSCE day is assigned to each examination.

The second stage focuses on the running of the examination which had been created in the previous step. Individual stations of the planned examination

are located either in several rooms specialised for specific stations, or in a single room. During the examination, observers are present at each station, overseeing the entire procedure and evaluating the student's activity. A group of student rotates among individual stations and the examination is finished at the moment when all students have attended all stations.

The last stage of an OSCE is dedicated to the overall evaluation of the examination, which can be done after the entire run is finished. At this stage, all results of students who have attended all stations are evaluated, and a feedback in terms of success is provided to all participants. However, the examination is not only evaluated from the students' point of view, but also from the individual stations' point of view, making it possible to evaluate the overall success rate of all students at individual stations.

2.3 Technologies Used in the Development

The SIMUportfolio is an application built on the modern PHP Symfony 4.4 framework (https://symfony.com/) together with the Twig template engine and the Doctrine ORM library for object mapping. In terms of databases, the PostgreSQL open-source object-relational database system was used. Yarn was used to manage dependencies on the frontend, and Composer was used to manage backend dependencies for third-party libraries. The Zurb Foundation framework, using the jQuery library, was used to develop a responsive frontend. The asset administration is dealt by the webpack's derivate so-called webpack-encore which comes with the Symfony.

Various JavaScript libraries were used for the purposes of individual modules, such as d3.js, NVD3 and Datatables (interactive visualisations of data), or select2.js, sweetalert2.js, jstree.js and featherlight.js (improvements in user experience).

A similar approach to the development of web-based applications has proven successful to us in the past, and a number of our projects have already been running with similar technologies (Dušek *et al.*, 2017; Karolyi *et al.*, 2017, 2019).

2.4 Pilot Runs

As part of the process of systematic innovation of courses dedicated to first aid and propaedeutics, pilot runs and testing runs of the platform have become the key moments for the development of the SIMUportfolio module aimed at the electronic support for OSCEs. Having created a new description of curriculum in the form of a set of learning units and learning outcomes, teachers and guarantors have been trying to find a suitable way of selecting topics to be newly examined by the OSCE method. These pilot runs have been extremely important for system developers, who have thus obtained valuable feedback from real users. Many iterations have progressively led to new functionality and control elements, aiming to optimise the final solution in terms of both effectiveness and user experience. Students themselves have also been involved in the process, particularly during the setup of pilot OSCE stations: in this way, teachers and OSCE guarantors could see whether the planned stations are manageable in the allocated time, and whether observers are able to record their evaluations via the SIMUportfolio platform.

3 RESULTS

The SIMUportfolio is a unique integration platform which fully supports the entire life cycle of OSCEs. It has been designed in a manner general enough to be used not only by the Faculty of Medicine of the Masaryk University, but in principle by any institutions that would like to use the OSCE method. A direct link to the curriculum is a key aspect; in other words, topics described in the curriculum and supplied with notes that they would be tested at OSCEs are actually later examined by this method. Everything is available online and stored in a database, which means that various issues can be traced back and analysed for the purpose of relevant feedback and further improvements.

3.1 Stage-designed Modules

As we have already mentioned above, OSCEs at the Faculty of Medicine of the Masaryk University can be divided into three main stages: (i) design and planning, (ii) running of the examination itself, (iii) evaluation of the examination and providing results (or feedback). These stages are reflected in the main modules in the SIMUportfolio platform.

3.1.1 The "Sketch" Module

The "Sketch" module allows the OSCE designer to define the stations and to plan the examinations. Apart from basic information about the station, its duration and instructions for individual participants,

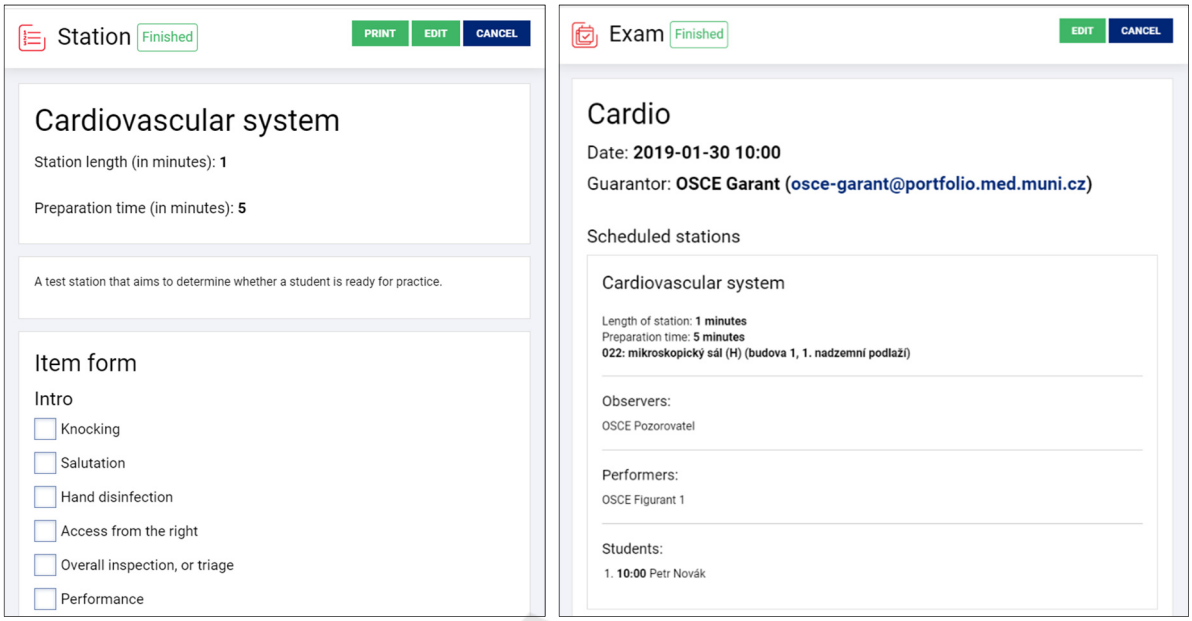

Figure 1: OSCE station and examination detail.

the designer also provides the contents of the itemised form and milestones of the examination. The individual items in the form can vary in terms of their type as well as scores that can be obtained for a correct answer. In the subsequent stage of planning the examination, the created station will be assigned to students for a specific date and time. The calculation of student succession and arrival times is performed automatically, in the application background.

Figure 1 shows details of a station and an examination that have been created inside the OSCE "Sketch" module. Apart from basic administrative data, there are also items such as the station's form, a list of students as well as instructions for participants (observers, students and simulated patients).

3.1.2 The "Execute" Module

The "Execute" module has been designed with the aim to be used by observers during the examination. Even before the examination, the observers can use it to go through the itemised form of the station and the list of students. Observers can also see all planned stations that have been assigned to given users (i.e. students). Each planned station involves a list of students in the order defined automatically by the system, with allocated schedules of their participation in that station.

After opening the station and starting the timer, the observer can see an itemised form which represents the scenario of a student's passage through the station. The observer watches the student and records all of his/her actions into the form (e.g. whether he/she did or did not perform a certain procedure, or evaluate the procedure on the scale from 1 to 5). All actions performed in the form are recorded and saved into that station's protocol. The form is automatically saved every 20 seconds in order to prevent data loss if connectivity was accidentally lost.

The observer finishes his/her work with the OSCE "Execute" module after all students have attended a given station. The results are then available in the OSCE "Report" module.

3.1.3 The "Report" Module

The OSCE "Report" module is the last component of the entire OSCE module in the SIMUportfolio platform. This environment has been primarily intended for guarantors of courses, who are responsible for the running of examinations as a whole. After an examination is finished, its guarantor can see its report (Figure 2), which sums up how individual stations were attended and what are the results of individual students. Detail of each station can be opened, providing a protocol of completion, i.e. the sequence of events that occurred in the evaluation form during the examination.

Several criteria can be used to evaluate the students, and these criteria can be defined before the start of the examination. For example, the student might be successful in a station if he/she carries out at

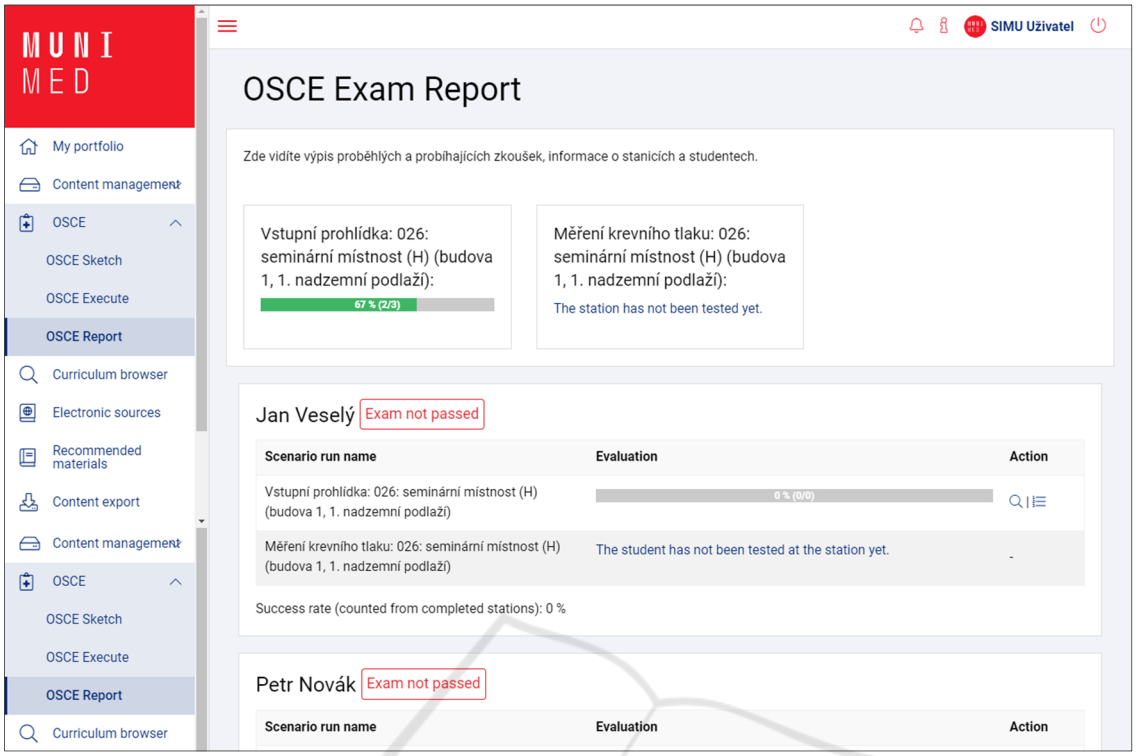

Figure 2: OSCE Exam Report for guarantor of the course.

least 70% of procedures that are expected of him/her. Additionally, the so-call critical points can be defined: if these points are not met, the student will be evaluated as unsuccessful. Note that OSCE designers are responsible for the setup of evaluation parameters. These designers should take into consideration the student's year, the difficulty of all stations in the examination and possibly also other factors.

Our plans for the future involve the extension of the OSCE "Report" module so that it is available to students who have passed at least one OSCE. In this way, each student would be able to look at his/her results at individual parts of the examinations (i.e. stations). In some stages of the study, this form of examination is not only intended for the student's evaluation, but also to provide feedback to that student in terms of his/her clinical skills. It is therefore worth considering whether the platform should be ready to records comments provided by observers (and possibly guarantors), which would then be made available to students themselves.

4 CONCLUSION

The SIMUportfolio platform has been continually maintained, developed and run at the Faculty of Medicine of the Masaryk University. Its development is linked to the SIMU+ project and it is envisaged to be used particularly in the context of the Simulation Centre (SIMU). Its employment in the teaching process has been gradual: a larger number of teachers and their topics have been progressively involved in the OSCE process. Theoretical and practical issues been conveniently solved thanks to the cooperation with partner universities from abroad, which have long-term experience in the domain of OSCE implementation; valuable lessons have been learnt and well-established principles have been further developed. The implementation of OSCE will always depend on the needs and facilities of a given institution and it cannot be objectively evaluated whether the resulting OSCE is better or worse than a similar approach elsewhere. The evaluation solely focuses on whether a given OSCE meets the expectations and objectives defined by the faculty. The platform sustainability is very good from the technical point of view, most notably thanks to the employed Symfony framework in its long-term

support version. The platform design and development have been done by an in-house development team, which can be considered as a significant benefit in the long term. Future prospects involve a number of ideas in terms of further development of the platform. From the points of view of both technology and methodology, it is possible and expected that intensive communication with users themselves will carry on, and that relevant requirements will be implemented in practice

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