Development of a Web based Immersive Patient Simulator as a curricular tool for OSCE preparation in surgery


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ABSTRACT

**Background:** OSCE (Objective Structured Clinical Examination) is a standard method of testing declarative and process knowledge in clinical core competencies. It is desirable that students undergo OSCE training before participating in the exam. However, establishing OSCE training is resource intensive and often limited in practice time. Web-based immersive patient simulators like ALICE (Artificial Learning Interface of Clinical Education) can possibly fill this gap as they allow the training of complex medical procedures at the user’s individual pace and with an adaptable number of repetitions at home. ALICE is known to positively influence knowledge gain and motivation.

**Aim:** Therefore, the aim of this study was the development of a simulator-based curriculum that teaches declarative and process knowledge and prepares for a real OSCE station. Furthermore, we wanted to test influence in knowledge gain and student motivation.

**Methods:** A specific curriculum was developed in order to implement the relevant medical content of two surgical OSCE Stations into the "ALICE" simulator framework. A total of 190 medical students were included in the study. 130 students participated in the study and were compared to 60 students in a control group. Students’ knowledge gain and motivation was tested at different points in time.

**Results:** The curriculum was developed according to the Kern cycle. Identification of the target group reveals that students, teachers, patients and the faculty possibly benefit from integrating ALICE into the curriculum. Seven virtual clinical cases were implemented with different teaching methods (structured feedback, keynote speech, group discussion and debriefing by a real instructor) in order to consolidate declarative and process knowledge. ALICE puts students in an active learner role as it uses constructive and interactive methods in order to promote knowledge gain and influences students’ intrinsic motivation. Working with ALICE had significant impact on declarative knowledge gain and OSCE performance. ALICE had no significant long-term effect when used as an additional training tool together with traditional sources. Students showed high levels of motivation and enjoyed working with ALICE.

**Conclusion:** ALICE offers web-based training for OSCE preparation and can be used as a selective didactic intervention as it has positive effect on knowledge gain and student motivation.
Keywords:
Immersive patient simulator; simulator-based curriculum; Objective Structured Clinical Examination; Artificial Learning Interface
Introduction

OSCE (Objective Structured Clinical Examination) is a well-established method in clinical education. OSCE aims to simulate clinical scenarios to test different core competencies such as physical examination, communication, clinical reasoning, medical interventions and knowledge of medical procedures [1]. In each OSCE station, students are given an assignment that tests at least one part of a predefined core competency. Performance is evaluated in an individual assessment by an experienced clinical physician.

Effective preparation for an OSCE requires learning and repetition of both declarative (“what to do”) and process (“how to do it”) knowledge. Less complex medical procedures such as resuscitation are usually trained on mannequin simulators [2]. More complex procedures such as clinical decision-making and workflows in diagnosis and therapy require small group training on standardised patients (SP) in a simulated OSCE. However, simulation of a complex OSCE situation with tutors, doctors and SP is resource intensive. Hence, OSCE simulation of complex procedures as preparation for the exam is often not part of the curriculum or only with limited practice time. Since the aim of OSCE is to prepare students for future clinical work it is desirable that they are given the opportunity to train OSCE without time pressure and limitations to number of repetitions before they enter the exam.

Immersive patient simulators (IPS) can possibly fill this gap. IPS are web-based software programs that allow repetitive training of medical procedures in a virtual environment [3]. With IPS, students can practice complex medical procedures at their own individual pace and with a suitable number of repetitions even on their computers at home. In a recent study, we developed a proprietary IPS (ALICE: “Artificial Learning Interface of Clinical Education”) and proved this had positive impact on clinical decision-making and student motivation [4].

In this study, we want to develop a simulator-based curriculum that imparts both declarative and process knowledge in order to prepare students for a real OSCE station. In a next step, we wish to measure the influence of this intervention on student performance in order to test the hypothesis that IPS are a suitable tool for effective OSCE preparation. Furthermore, we wish to measure student acceptance of this educational tool.

Material and Methods

Two different surgical OSCE stations were chosen for this experiment. One station simulates a patient with a trauma diagnosis (fracture of distal radius) whereas the second station simulates a more complex patient with a clinical situation from general surgery (abdominal pain = appendicitis).
In order to represent the corresponding original OSCE stations in the existing simulator, we created a new curriculum that specifically covers the steps that are necessary to implement the relevant medical content into the “ALICE” simulator framework. Curriculum development was based on Kern’s curriculum planning cycle [5] which includes the following steps: 1. Problem Identification 2. Targeted Needs Assessment 3. Goals 4. Educational Strategies 5. Implementation 6. Evaluation and Feedback. As the problem (Step 1) was basis for the study, curriculum development starts at Step 2.

Design and technical realisation of ALICE were previously described by our group [6]. In brief, ALICE is a web-based immersive patient simulator that allows the student to navigate through a virtual “game like” environment from a first-person perspective. (Figure 1).

ALICE simulates a treatment room with a simulated patient where the user can interact with a virtual patient and additional non-player characters (NPC) such as nurses and other doctors. The simulator starts with a short introduction that teaches basic simulator controls and usage. The user is able to freely interact with the environment and treat the virtual patient. The student instantly receives the desired reaction from the simulator, either as an answer from the virtual patient or as tables (e.g. laboratory values), images (e.g. x-ray, electrocardiogram), or videos (e.g. computed tomography scans, ultrasound). The user is free to choose between all available tests and there is no restriction on medically indicated

Figure 1 Impressions of ALICE where students navigate freely and treat virtual patients
When student chooses an examination not medically indicated, the test shows a normal finding. The simulation ends when the student chooses a diagnosis and initiates the necessary treatment. ALICE stores the user behaviour at the server level, logging students’ decisions. For this study, ALICE was expanded with the corresponding declarative knowledge and virtual patients who represented similar cases as simulation patients in the OSCE.

190 medical students were included in the study. 130 students were in the study group whereas 60 students were in the control group. Evaluation was approved by the Educational Committee of the Medical Faculty at the University of Cologne. The Institutional Review Board was informed and there were no objections. In order to test the impact of simulator use on OSCE performance, the study group was divided into a long-term and a short-term group. Short-term effect was tested on the trauma case with 100 students: in a first stage, students answered 11 multiple-choice questions (MCQ) for testing declarative knowledge. In a next stage, they participated in a simulated trauma OSCE for testing process knowledge. Correct results of MCQ and OSCE were not revealed at this point. In a next stage, students worked with the simulator and then finally repeated the MCQ and OSCE with the same clinical scenario as before (Figure 2). Correct results were then revealed and discussed in a peer to peer debriefing and finally with an experienced doctor.

Figure 2 Group distribution: 130 students used ALICE and were compared to a control group with 60 students
Long-term effect was tested on 30 students in the general surgery OSCE station, as the diagnostic workflow is more complex than in the trauma OSCE. These students used ALICE at least 3 months prior to OSCE as an additional preparation tool and were compared to a control group of 60 students who prepared for OSCE without the use of ALICE. In this case, the clinical assessor was “blinded”, i.e. unaware which group was which.

Student acceptance and their opinion about the effectiveness, applicability and impact on motivation were determined by means of a questionnaire using a (forced choice) 6-point Likert scale.

Data was analysed using the McNemar and Student t test. P< .05 was considered significant. Data were analysed using the SPSS software package version 20.

OSCE performance was measured by testing the underlying theoretical (declarative) knowledge according to the predefined learning goals based on the German national medical examination regulations. Moreover, procedural knowledge, as basis for OSCE performance, was measured by testing the following items: correct diagnosis, correct therapy, and correct workflow in anamnesis and diagnostics. These workflows were designed as a blueprint reflecting the “optimal” workflow suggested by two independent senior surgeons.

**Results**

Curricular development according to the Kern cycle:

*Targeted Needs Assessment: Identification* of the target group of this curriculum reveals that students, teachers, patients and the faculty possibly benefit from such an intervention. The main target group of the curriculum are the students based on the demands of a better medical education. Teachers benefit because students are possibly better prepared when entering small group training. As successful OSCE is a prerequisite for working at the bedside, students are better prepared when working with real patients, which promotes patient safety and satisfaction. The faculty also benefits as this method is cheaper and less elaborate than traditional OSCE.

*Learning goals* were defined and are summarised in Table 1.

<table>
<thead>
<tr>
<th>After working with ALICE, students should…</th>
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<tr>
<td>know the underlying basics in anatomy, physiology, pathophysiology and surgery.</td>
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<tr>
<td>assign specific symptoms to corresponding diseases.</td>
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<tr>
<td>identify the symptoms of virtual patients that are specific to a given disease.</td>
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<tr>
<td>weigh pathological findings and bring them into the clinical context.</td>
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<tr>
<td>demonstrate correct workflow in diagnostic and therapeutic decisions (clinical reasoning).</td>
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<tr>
<td>make the correct diagnosis and choose the correct therapy.</td>
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Table 1 Learning goals for OSCE Intervention

*Educational goals:* The simulation itself covers different teaching methods. ALICE starts with a short animation that covers simulator usage. The user is asked to explore the surroundings and familiarise themselves with their avatar in the virtual world. After treatment of the first virtual patient, the user is given structured feedback and a keynote speech from the virtual instructor. These two methods allow teaching of both declarative and process knowledge. After finishing the cases, students first have a group discussion with other students after which are finally debriefed by a real instructor of the educational level of a medical doctor. These methods consolidate declarative and process knowledge.

Cognitive Engagement was designed according to the ICAP framework (Interactive, Constructive, Active, and Passive [7] which defines cognitive engagement activities. Working with the simulator puts students in an active learner role and finding the right diagnostic and therapeutic workflow is constructive. Both factors are known to promote knowledge gain and influence students' intrinsic motivation [8]. Group discussion is highly interactive and this is thought to have a positive effect on learners' performance [9].

The framework of medical content was based on the national learning objectives catalogue. Virtual instructors accompanied the students during their cases in the sense of a virtual cognitive apprenticeship. This framework was withdrawn step by step according to the number of correct clinical decisions and correct diagnoses made by the students.

**Implementation:**

ALICE was modified in order to meet all curricular requirements. For this study, ALICE covers 7 different clinical cases (Table 2).

<table>
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<tr>
<th>#</th>
<th>Trauma</th>
<th>Visceral</th>
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<tr>
<td></td>
<td>Patient</td>
<td>Diagnosis</td>
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<tr>
<td>#1</td>
<td>Distal Radius Fracture</td>
<td>Conservative</td>
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<tr>
<td>#2</td>
<td>Distal Radius Fracture</td>
<td>Reposition + Surgery</td>
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<td></td>
<td>(Smith)</td>
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<tr>
<td>#3</td>
<td>Distal Radius Fracture</td>
<td>Reposition + Surgery</td>
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<td>(Colles)</td>
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<tr>
<td>#4</td>
<td>Distal Radius Fracture</td>
<td>Conservative</td>
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Table 2 Clinical cases added to ALICE for this study

**Evaluation:**
Influence of simulator use on declarative knowledge was measured by comparing the pre and post-simulator questionnaire in 100 students. The number of correct answers increased significantly between the pre and post questionnaire (7 out of 11 compared to 9 out of 11, \( p=0.0056 \)) (Figure 3). Hence, working with ALICE showed a positive impact on declarative knowledge gain.

Figure 3 Working with ALICE showed impact on declarative knowledge

Short-term effect of simulator use on OSCE performance was tested in 100 students by comparison of trauma OSCE before and after working with ALICE. Students showed a significant increase between Case 1 and Case 4 in OSCE performance (\( p=0.034 \)) after working with ALICE in terms of all parameters. Hence, working with ALICE increased the amount of process knowledge. (Figure 4)
Figure 4 Working with ALICE showed impact on process knowledge (X axis = number of students)

Long-term effect on procedural knowledge was measured by comparing students who used ALICE prior to OSCE as an additional training tool for a more complex case (acute abdomen) and students who prepared with other sources. Comparison between final case in ALICE and OSCE revealed that although there was a trend favouring the OSCE group, the simulator
showed no significant long-term impact on OSCE performance when adding ALICE to commonly used sources like books etc. (Figure 5).

Figure 5 Working with ALICE had no significant long-term effect on OSCE performance in comparison to a control group.

In the descriptive analysis, students showed a high level of motivation when working with the simulator. They enjoyed simulator use and recommend working with such a simulator. They
felt they learned new topics and demanded more interactive content in their curriculum. The majority of the students would use such a simulator frequently and believe that IPS can prepare for future work. The overall impression of the simulator was good. Interestingly, students displayed a normal relationship with technology as the proportion of casual users to power users (that have computers as a hobby and use them every day) was normal (Figure 6).

Figure 6 Likert scale reveals high motivation when working with ALICE.

Discussion

The current study reveals that ALICE is a suitable tool for OSCE preparation. ALICE was designed as a low-cost 3D immersive framework which makes it possible to add different clinical cases in a web-based scenario with learning that is not time or location dependent. This enables learning at the individual’s own pace and with the number of repetitions appropriate for them. Differences in knowledge levels can be evened out and future performance can potentially be raised. However, IPS can only be used as a support for a real OSCE training in terms of a blended learning concept since the degree of reality created by these simulators nowadays is not yet of suitable quality.

Moreover, IPS are limited to simulating clinical decision-making based on defined guidelines or clinical blueprints. In this current feasibility study, we used a comparatively simple OSCE station: interpretation of X-rays and a limited number of possible clinical decisions enables a steep learning curve [10]. However, more complex scenarios are technically possible [11] but impact on OSCE performance was not yet proven for these modules. This is supported by the fact that the more complex case in our study did not show a significant rise in process knowledge gain. However, this is likely due to the fact that there was a rather long interval
between ALICE usage and OSCE. Furthermore, ALICE was only used as an additional tool for preparation. This is inevitable as students cannot rely on such a tool before it is evaluated and really shows proven effect on knowledge gain. A study that compares students who used ALICE exclusively for preparation of a complex case and students who prepared with conventional learning methods is desirable and part of future studies. However, the current study reflects reality, as most learners do not rely on only one knowledge source when preparing for an examination.

ALICE shows a positive impact on learners' motivation and both declarative and procedural knowledge. However, these findings may be influenced by the fact that participation in this study was on a voluntary basis which is known to possibly bias the result as motivated students more often agree to participation than less motivated students [12]. This impact can possibly be attenuated by the fact that students participated mainly because of financial recompense rather than due to an intrinsic motivation. It is important to note that learners do display different learning styles and thus not all learners are equally responsive to this educational tool [13]. Hence, the results cannot be generalised for all students.

Embedding such a simulator in an educational environment requires decent curricular planning and consequently implementation of this curriculum into the simulator. This initial investment pays off once the simulator can be used as an alternative to established teaching methods with high running costs. Motivation is known to have a strong effect on knowledge gain [14]. ALICE supports motivation by offering exploration of an immersive world with freedom of choices and treatment of the user’s own virtual patients. These factors promote experience of autonomy and competency which can directly affect intrinsic motivation [15]. Extrinsic motivation was enhanced by applying features that are commonly used in video games such as reward systems (badges, points, rank), continuous feedback and leader boards for students [16].

The use of IPS for psychomotor or communicative learning goals is already described in literature and its effect on knowledge gain in these settings is still not proven. Adding these competences to the ALICE framework is part of future studies.

**Conclusion**

ALICE is a valuable tool for teaching declarative and process knowledge in a web-based setting. It shows positive impact on knowledge gain and student motivation and hence enriches the toolbox of didactic methods for OSCE preparation.
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Conflicts of Interest

The authors declare that they have nothing to disclose
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