Piloting of Virtual Patient-Based Online Self-Study Quizzes for Developing Undergraduate Medical Students' Clinical Reasoning Skills

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Abstract

Clinical reasoning – the application of medical knowledge to a patient's problem – requires training in a safe environment. With learning tasks based on Virtual Patients (VP-tasks) the clinical setting can be simulated in a save way and these tasks can be easily integrated into blended-learning environments as synchronous tasks (face-to-face or online) or as asynchronous online tasks. This article presents the editorial process for developing VP-based self-study quizes (SSQs) and analyses field-study results on students' learning experiences and study habits. The editorial process initially only involved experienced clinical, educational and technical experts. To better match the tasks' difficulty to the knowledge level of the students, junior doctors and advanced medical students joined the editorial team at a later stage. Students (n = 351) agree that the SSQs (n = 10) developed by the expanded team match their knowledge better than the SSQs (n = 13) developed by the initial expert editorial team. Additionally, the students rate the online SSQs as more helpful than the similar face-to-face VP-tasks. The students' free comments indicate their high acceptance of the SSQ-format.

The SSQ-format is a feasible option for providing systematic online training in clinical reasoning, especially when working with a multi-level-educational editorial team and when the editorial work is driven by a systematically structured blueprint of topics and learning goals.

***Keywords*:** Virtual patients, Clinical reasoning, Quiz development, Editorial process, Self-study quiz

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1 Introduction

Clinical reasoning is a crucial competence for physicians. As a complex cognitive skill, clinical reasoning requires wide medical knowledge and comprehensive procedural knowledge on how to apply medical knowledge, when diagnosing and treating patients' problems (Braun, Zwaan, Kiesewetter, Fischer, & Schmidmaier, 2017). Faulty clinical reasoning processes result in diagnostic errors and put the safety of patients at risk as demonstrated by the rate of diagnostic errors uncovered in autopsies (8.0–22.8%) (Shojania, Burton, McDonald & Goldman, 2002).

Medical educators have been and are still looking for ways to develop the clinical reasoning skills of medical students systematically in the workplace while ensuring patient safety (Wagner-Menghin, Hirsch, & Pokieser, 2018). Due to the considerable increase of medical students over the last centuries, the emergence of numerous disciplines in medicine and the limited resources in teaching hospitals the exposure of students to real patients is limited. Thus, developing clinical reasoning skills systematically in classrooms gained importance (Hege, Kononowicz, Tolks, Edelbring & Kuehlmeyer, 2016).

During the 20th century information technology (IT) became increasingly common for communicating remotely and for documenting patients' symptoms, problems, and treatment plans. This facilitated compiling authentic medical case material as Virtual Patients (VPs) for case-based learning (CBL) in the classroom. Furthermore, organising online learning with blended learning scenarios including VPs, has been facilitated by employing web conference systems and learning platforms, which proved crucial in light of recent developments related to the outbreak of Covid-19.

CBL is a highly accepted experiential tool for teaching and learning clinical reasoning skills. Students apply previously acquired medical knowledge when engaging in clinical cases. Thus, through CBL the students learn how their medical knowledge contributes to later clinical practice. As such, CBL pro-

motes self-directed, active learning, increases motivation and promotes deeper conceptual understanding (Thistlethwaite et al., 2012; Turk, Ertl, Wong, Wadowski & Loffler-Stastka, 2019). For students that do not have the opportunity to reach relevant learning goals by bedside-teaching, VPs are a convenient supplement as VPs can serve a large number of students simultaneously (Hege et al., 2016). The complexity of interactive online-VP scenarios can be adjusted to the ability level of the learner by including irrelevant information as decoy, emotionally complex situations or time pressure (Hege, Kononowicz, Berman, Lenzer & Kiesewetter, 2018). These scenarios can also provide immediate feedback, allowing the learner to study purposefully and to focus on individual areas of weakness. To train the clinical reasoning process of students and strengthen their pattern recognition of different illnesses, it is recommended to create a large pool of short and focused VPs with varying complexity and a variety of problems (Hege et al., 2018).

2 Piloting systematic, classroom-based online learning with Virtual Patients

In 2017/18 Virtual Patient-based learning tasks (VP-tasks) in the format of online self-study quizzes (SSQs) were introduced to the curriculum for undergraduate medical students at the Medical University of Vienna in their 5th year of the human medicine programme at Medical University of Vienna. Furthermore, an editorial process for managing the collaboration of the various experts involved was initiated. A field study evaluated the students' learning experiences and study habits. The following chapter presents the editorial process, the didactic features of the SSQs, and the field-study results on the students' learning experiences and their study habits related to SSQs.

3 Results

3.1 The editorial process

An experienced Event- and Content-Manager (ECM) directs the editorial process for each set of VP-tasks. The ECM keeps track of each step and the editorial deadlines and arranges the required editorial meetings.

Defining the quiz's general topic
The editorial process starts by clarifying the topic and the overarching learning goals that should be covered. Typically, the Module Coordination, who commissions the production of a quiz, draws on material such as the study curriculum and up-to-date learning-objective-catalogues (Medizinische Universität Graz, Medizinische Universität Wien, Medizinische Universität Innsbruck & Medizinische Fakultät Linz, 2020) to define the general topic of a quiz.

Establishing the collaboration with a clinical expert
Equipped with a list of general topics and/or overarching learning goals that should be covered in the quiz the ECM contacts a content expert, who is clinically active. After a collaboration is agreed on the ECM arranges a meeting between the clinical expert and a member of the editorial team.

Editorial work with the clinical expert – 1st review from the learner's perspective
Based on discussions with the editorial team, the clinical expert chooses a specific case that is suitable to illustrate the clinical decision making and reasoning process related to the given learning objective and theme. The expert then anonymises the patient material. Subsequently, members of the editorial team (junior doctors or advanced medical students), who introduce the learners' perspective, work with the clinical expert to develop clinical decision prompts, which are phrased as open questions and should guide the students through diagnosing and treating this VP from the perspective of a clinician. Additionally, the clinical expert or the editorial team phrases so-called expert answers for the prompts providing a state-of-the-art solution and further explanations.

Didactic and technical review – 2nd review from the learner's perspective
The didactic and technical experts of the editorial team review and edit the clinical decision prompts and expert answers to meet the required didactic and technical standards.

Additionally, the experienced medical students on the editorial team take on the learners' role and try to complete the prompts and to understand the expert answers. This step ensures that the challenges provided by the prompts match the learners' medical knowledge adequately and are not set too high (or too low).

Implementation into the e-learning platform by the technical team
The moodle quiz-tool is used to gradually present the clinical setting, the unfolding patient's story, the clinical decision prompts, and the expert answers.

Release and post production
The ECM releases the finalised online SSQ for the student cohort. During the run time of the quiz, the ECM monitors the students' learning behaviour, sends deadline reminders and organises technical fixes. Questions concering the quiz content are forwarded to and answered by the clinical expert.

3.2 The didactic features of a self-study quiz

Clinical reasoning is a highly cognitive process. Beginners need to be tasked with making and justifying a clinical decision (= apply medical knowledge). They also need to be provided

with insights into the cognitive processes underlying the performance of experts (Stalmeijer, Dolmans, Wolfhagen & Scherpbier, 2009). As such, a SSQ starts by presenting the patient record in an authentic clinical setting and a prompt, requiring the student to come up with a clinical decision (*Figure 1*).

Upon responding to the first prompt, the student is provided with the expert answer and tasked to evaluate the concordance of their own approach with the expert answer. (*Figure 2*).

The quiz continues by presenting further prompts and expert answers. The prompts in our SSQs simulate the clinical tasks of a 6th year medical student. Each SSQ was designed to take students 15–25 minutes to complete.

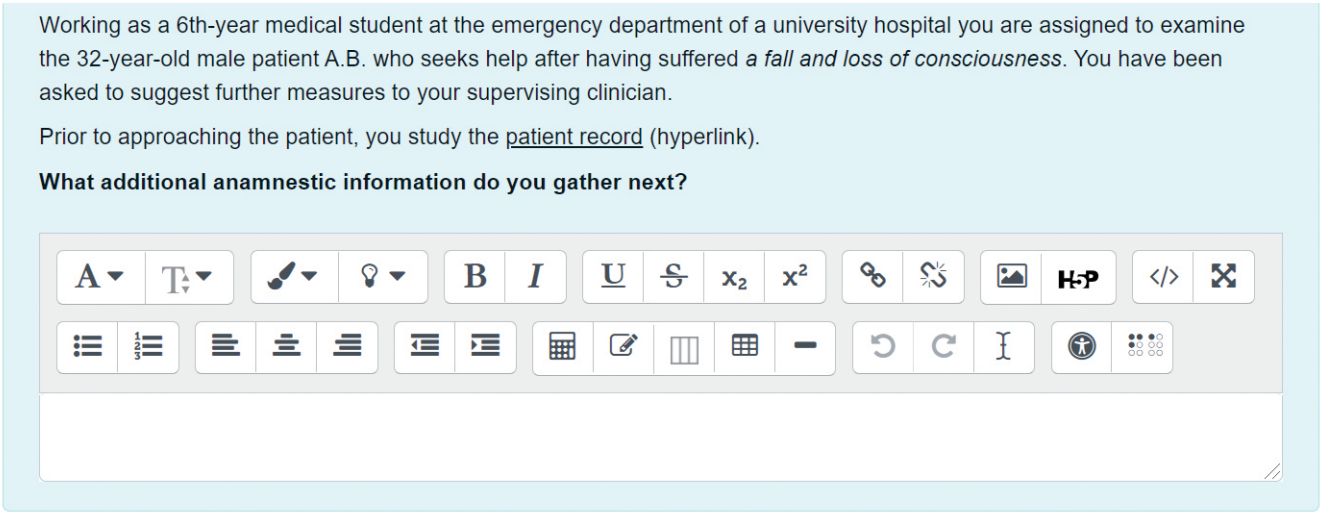

Figure 1. Simulating an authentic clinical situation in a self-study quiz (SSQ): clinical setting = emergency department, patient' situation = 32-year-old patient describing 'a fall and loss of consciousness', student's task = examine the patient, clinical decision = what additional anamnestic information do you gather next?

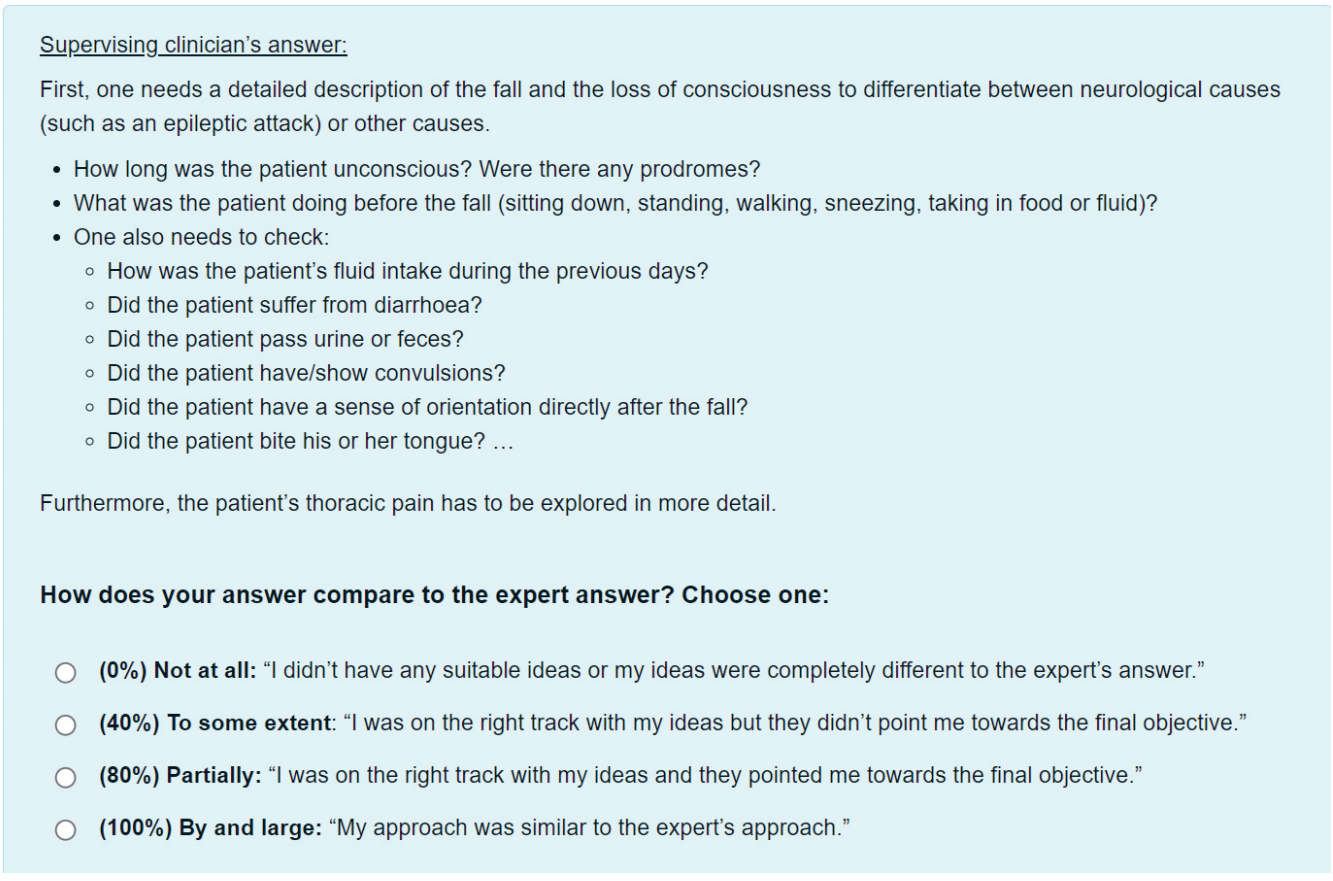

Figure 2. Providing students with insight into the expert's approach.

3.3 Students' learning experiences and study habits related to SSQs

Sample, material, and setting

The 2017/2018 cohort of 5th year medical students (n=624) were invited to participate in the study and to complete an online-questionnaire after having completed the last online assignment of their course on diagnosing and treating patients. 404 students consented to having their concordance ratings and their free comments for each quiz included in this study. In the online questionnaire 351 of these students gave information on study habits, rated the helpfulness of the learning activities (SSQs and interactive presentations) and judged how well the SSQs' difficulty matched their knowledge.

For 5th year medical students thirteen SSQs for the winter term 2017/18 and ten for the summer term 2018 were developed as part of a weekly scheduled, blended-learning course on diagnosing and treating patients, covering a broad variety of medical disciplines. It was recommended to students to complete the online SSQs at home prior to attending the face-to face interactive presentation (F2F, IP-task) in the lecture theatre together with the whole cohort. In the F2F IP-task cases and tasks that are structurally similar to the cases and tasks of the SSQs are presented and students are encouraged to share their clinical approach by discussing the questions quietly with the students next to them before sharing an answer with the presenter and the audience using the lecture's live-chat function. When the buzzing of these 'buzz-groups' (IP/buzz group task, F2F) in the lecture theatre dies down and the chat shows some relevant answers, which approximately takes 60 to 90 seconds, the clinical expert continues with the case presentation to share the expert approach in a short summary (IP/case summary, F2F) and comment briefly on students' answers in the chat.

The editorial team for the winter term consisted of content, didactic and technical experts; in the summer term, near-level peers were included to achieve a better match between task difficulty and student knowledge to boost motivation during self-study. The SSQs included in average 5,4 tasks (min = 3/max = 8) and could be completed by most of the students within 15–20 minutes. The interactive presentations also included 3–5 tasks per presentation and were scheduled for strictly 15 minutes.

Helpfulness ratings and free comments

Students rated doing the online SSQ tasks and the concordance ratings at home as being more helpful for learning than participating in the interactive presentation's face-to-face buzz-group tasks and the presentation of the case summary in the lecture theatre with the whole cohort. Chi^2 tests indicate a difference between the SSQ-task distribution and the IP-buzz group-tasks distribution ($Chi^2 = 168{,}315$; $df = 3$; $p<0{,}05$) as well as between the SSQ/concordance rating distribution and the IP/case summary distribution ($Chi^2 = 199{,}575$; $df = 3$; $p<0{,}05$) (*Figure 3)*. On average 9% (SD = 3%) of the students gave free comments per quiz, expressing predominantly (76%) satisfaction (e.g. 'great case' or 'thank you!') or neutrality (e.g. 'nothing in particular').

Matching the tasks' difficulty and the students' knowledge

Only about half of the students indicate to have 'rather enough knowledge' (52%) or 'enough knowledge' (2%) to work on the winter term tasks. For the summer term tasks this share in-

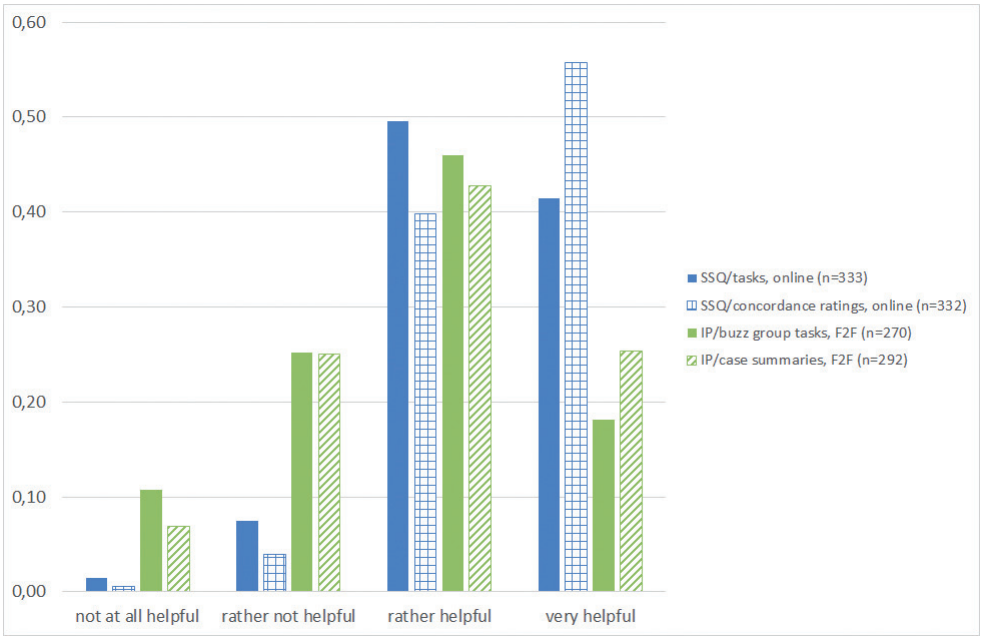

Figure 3. Helpfulness ratings (relative frequencies) for Virtual Patient tasks – summer term; SSQ = self-study quizzes; IP = interactive presentations; F2F = face-to-face.

creases up to 78% ('rather enough knowledge') and 7% ('enough knowledge'; $Chi^2 = 153{,}768$; df = 3; $p<0{,}05$; N = 328).

Study habits

Students' self-evaluation resulted in a mean concordance score of 82% (SD = 9%). The majority of students rate themselves as being 'rather critical' (70%) or 'extremely critical' (10%) when evaluating the concordance between their approach and the expert's approach. About half of the students consider finishing each quiz with a high concordance score as 'rather important'. The majority of students indicate to 'often' (31%) or 'sometimes' (44%) use reference material when working on the quizzes.

4 Discussion

In general, the use of VP-tasks and online SSQs enriches the training of undergraduate medical students and offers many benefits for teachers of medicine as well as medical students. We successfully piloted the use of online SSQs in the human medicine curriculum of the Medical University of Vienna by implementing the described editorial process to produce the 23 SSQs as well as the matching 23 interactive presentations. The editiorial approach of having the tasks for the learning activities edited not only by the content experts, but also by a multi-level-educational editorial team proved beneficial. When medical students are involved in the editorial process they can give feedback to clinical experts on which tasks are manageable for students of this educational level. Matching the tasks' difficulty and the students' knowledge is expected to have a positive impact on study motivation. However, we have no data on this so far.

Our field study on self-reported study habits of students showed that online SSQs, which were completed at home, were considered more helpful than the study activities during the F2F-lecture in the large lecture theatre. Especially the possibility to compare one's own approach to the expert answers was considered very helpful when studying online. In theory, students can also compare their approach with the expert's approach during the F2F-lecture. Thus, this result may be percieved as counterintuitive at first sight and we have no data on why students do not take advantage of this opportunity during the F2F-lecture. However, considering the busy atmosphere in the lecture theatre with more than 400 students in combination with the strictly scheduled interactive presentation, which can only last 15 minutes, one may understand why students prefer the self-paced, more quiet environment when working on the online SSQs at home. During the rather busy lecture in the lecture theatre students might have problems focusing on studying. One might also speculate that students are more prepared to engage in the most likely difficult reflection process of comparing their approach with the expert answers, when studying on their own as they can work at their own pace, which is not the case during the lecture.

The majority of students state to 'often' or 'sometimes' use reference material when working on the quiz and to be 'rather' or 'extremely' critical when rating their own performance. This result is supported by the mean concordance score of 82%, indicating that students see room for improvement in regard to their performance. Both results are quite promising in terms of self-regulated learning. Timely feedback on the performance of students is essential to drive learning, especially when errors occur, since learners learn best from errors if they receive feedback immediately and when they can see why an error happened and how it can be prevented in future (Heitzmann, Fischer, Kühne-Eversmann & Fischer, 2015; Kilminster & Jolly, 2000). The combination of clinical decision tasks and immediate feedback can, therefore, reduce the misperception of understanding, support students with weaker learning prerequisites to seek help efficiently and serve as 'real time clinical guidance' for the learners (Hege et al., 2016; Heitzmann et al., 2015).

Despite the promising results on the helpfulness of the SSQs, the efficiency of the editorial processes and favourable effect of the SSQs on self-regulated learing, we need to acknowledge that these results are based on a field study using a questionnaire based approach. We chose this approach to observe medical learners in a typical learning situation, however, this came with the limitation of not being able to strictly control the sequence of working on the SSQs and the participation in the IP. Due to limited resources it was also not possible to evaluate the quality of the students' self-rating by having their answers rated by an expert. To validate these results experimental studies need to be done.

Many factors limit student exposure to real patients and to bedside-teaching (Poulton & Balasubramaniam, 2011). VP-tasks can not only be prepared systematically based on learning goals, but can also serve a large number of students simultaneously either in a face-to-face or an online learning setting. VP-based SSQs allow self-paced and self-directed study. The clinical decision prompts followed by immediate feedback require the use of medical knowledge in a specific clinical situation and, thus, foster 'the bridging of theory to practice' as well as contribute to the development of clinical reasoning skills.

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