iCoViP

Guideline on virtual patients integration into health professions curricula

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Step I. Problem identification and general needs assessment

Guiding questions:

1. Why should I have VPs in the medical curriculum?
2. For what purpose should I be using VPs?
3. What are the pros and cons of integrating VP into the curriculum?

Theme: Goal in the curriculum

All medical schools should strive to have virtual patients (VPs) in their curriculum, as these are important tools for students on their way to become health professionals, offering them an authentic, comparable, interactive, patient-centered and safe learning experience.

VPs are employed as a tool for curricular integration that requires the students to combine and apply knowledge from several disciplines in one activity. At the curricular level, VPs offer greater consistency and reliability in the delivery of learning experiences. In a blended learning curricular model, the virtual curriculum runs alongside the existing face-to-face curriculum, giving educators the flexibility in selecting methods to meet the learning objectives. [Tworek10].

The versatility of skills that can be taught with VPs encourages many educators to try to embed this teaching method into the medical education curriculum for several purposes. [Sobocan17]. Virtual patient panels are being used in health professions education to facilitate the development of clinical reasoning skills, resource utilization and longitudinal patient care, as well as knowledge acquisition, and clinical skills training. [Hege16], [Kononowicz15] [Quail19]. Exposure to VPs also can help students to develop non-technical skills such as decision-making, teamwork, communication skills, but also self-awareness and self-confidence. It is especially common to see a recommendation to apply VPs in support of clinical reasoning training [Cook09], [Plackett22], because VPs are giving the students an opportunity for deliberate practice of patient diagnostic and management skills. Using virtual patient panels, students compare and contrast similar clinical findings and have to weigh different options based on the relative probability of each diagnosis and the typicality of findings [Mayer22].

VPs also provide clinical and contextual diversity in case collection [Bowden21]. The coverage of various subjects and possible situations that can appear in real-life medical activities is an important factor in the expected effect of VP training [Doloca16]. VPs allow efficient presentation of multiple patient visits, and in accelerated time-perspective how diseases change over time and interact with several factors including genetic background, psychosocial context and comorbidities [Smith07]. VPs, unlike the textbooks or most lectures are interactive, in addition provide access to multimedia materials, possibility to check reference sources, reflect in the decision-making process and to make mistakes and learn from them [Botezatu10a]. VPs allow students to safely apply obtained knowledge without putting at risk either themselves or patients [Edelbring11] [Kulasegaram18].

VPs act as a link between students' factual knowledge and the clinical environment [Ellaway15]. This provides students with an opportunity for productive struggle within the context of authentic clinical situations. VPs help students to discover new concepts, structure and then apply their knowledge in face of the ambiguity, complexity or uncertainty of medical practice [Kulasegaram18].

You should consider VPs as an opportunity for your students, if you are looking for a tool to increase their exposure to patient cases beyond what is possible in the clinic. VPs give the students the possibility to be confronted with a wide variety of diseases, symptoms and clinical scenarios, permitting (i) to overcome limitations in exposure to real patients (e.g., lack of contact with rare diseases or presentations or differences across groups of students on the types of patients they meet [Cederberg12], [Posel12]), (ii) to meet institutional or national curricular objectives [Hege16], (iii) to offer an authentic experience in early stages of the medical curriculum free of ethical concerns [Washburn20].

It is fair to say that VPs in the curriculum are not a silver bullet to solve all problems and they also have drawbacks when misused. VPs should not limit access to real patients as this is the gold standard in medical education. Consider for instance the limitation of VPs in terms of physical examination or history taking. Some types of VPs may deteriorate soft skills of students (e.g. showing empathy), when students focus too much on finding the right diagnosis and forget the human-aspects of patient care. Finally, it is tempting for some teachers to trust the VPs will replace them in the role of teachers in assessment or providing feedback and by that save their time. VPs, as many other educational technologies, are just tools to aid the educator, but without good supervision the students will feel lost in their education or learn to game the system.

Recommendations:

- VPs are great tools for curricular integration, that requires the students to combine and apply knowledge from several disciplines in one activity.
- Versatility of skills can be taught with VPs, choose how you can utilize them.
- VPs act as a link between students' factual knowledge and the clinical environment.
- Utilize VPs to address knowledge gaps, to ensure more comprehensive learning experiences, to provide otherwise unavailable clinical experiences and to guarantee availability of standardized material.

Step II. Targeted needs assessment

Theme: Phase of the curriculum

Guiding questions:

1. Into which level of medical curriculum should I implement virtual patients (VPs)?
2. What is my target group?
3. Should VPs be created for students in pre-clinical, clinical years or maybe for all students?

Medical education across the world may be based on very different types of curricula. Virtual patients could be part of a traditional pre-clinical and clinical course, an integrated/systems-based course, problem-based learning (PBL), case-based learning (CBL), enquiry-based learning (EBL), multi or inter-professional learning course. As a teacher you need to be flexible and choose the solution that will fit best to your own curriculum and your needs.

The literature is not clear on the exact best time to introduce the VPs into curricula. The general recommendation that emerges from the literature is not to start too early with introducing VP's into the curriculum as the baseline knowledge or interest of undergraduate medical students might be limited [Radon11]. The prerequisite is that students should be learning semiology subjects (when they learn about signs and symptoms).

There is a variation in recommendations for VPs integration time. Some authors are of the view that VPs should start in the early stage of medical education [McCarthy15]. Medical students prefer to use VPs in their early years (i.e., 2nd year [Gesundheit09]), when they don't yet have access to patients in a clinical setting, in contrast to higher years' students, where the interest declines. This is reversed in the last (6th) year, when they want to acquire more clinical experience before becoming an independent doctor [Dafli19]. On the other hand, Postma et. al. (2015) shows that the accuracy and precision of the third-year students who participated in the intervention were in fact similar to the scores of the fourth- and fifth-year students [Postma15]. Generally most of the VPs in medical curricula were introduced in years 3 and 4 [Kononowicz19]. Depending also on your teaching setting and how specific the topic you want to cover is - it might be valuable to divide your VPs collection into undergraduate and postgraduate [Kolb09].

The question that may also arise is about the level of difficulty of VP's that should be introduced to the students. Here both Huwendiek et al. and Kulasegaram et al. agree on progressive introduction of complexity in different clinical skills, clinical reasoning or the design in relation to VPs cases [Huwendiek13], [Kulasegaram18] e.g. uncommon clinical pictures to be recognized and multitude of influencing (contextual) factors to be considered by the students while solving a VP. When students have less experience and knowledge, VPs should be less complex, and the complexity should be increased along with the growth of knowledge and experience during the transition through the curriculum. Dahri et al. observed problems with finding the VPs difficulty level appropriate by 1st year students in comparison with 2nd and 3rd year students, they also did not find VPs very helpful in learning about the main signs or symptoms [Dahri19].

Recommendations:

- To work on VPs students should have some baseline knowledge e.g. in semiology.
- There is variability in recommended VPs' integration time: early years - for patients' exposure before clinical years, late years - to acquire more clinical practice before becoming independent health professionals.
- Complexity of VPs (in clinical skills, clinical reasoning, design) should be increased along with the growth of students' knowledge and experience.

Theme: Effective use of resources

Guiding questions:

1. How to deal with barriers due to limited funds?
2. How to deal when you do not have enough expertise?
3. What to do when you have no computer rooms or other elements of technical infrastructure?

One of the often quoted barriers in implementation of virtual patients are their costs. In a well-known study carried out at U.S. and Canadian universities by Huang et al. [Huang07] the average costs of developing one virtual patient were reported to be in the range of $10,000 - 50,000 without maintenance costs. Other types of costs include: faculty development, teacher salaries, IT infrastructure and staff, classroom use, etc. The VPs and the software needs to be updated [Haag10]. Altogether it amounts to a total that appears to many teachers as an insurmountable barrier. How to deal with that?

The costs of VPs should of course not be ignored, but the good news is that with enough determination there are ways to deal with this issue. The best proof for that is the fact that VPs are reported to be in use on all continents (except Antarctica) both in countries with high and low income [Kononowicz19]. Below are a few tips on how to succeed if the budget for VPs is limited.

First, it is important to reduce expectations of perfection in aesthetics and technical sophistication. The entertainment industry and press releases reporting on innovative virtual reality research projects create a demand unrealistic to satisfy on graphical fidelity in presentation of the VPs and the simulated clinical environment. Many expect VPs to contain advanced artificial intelligence-based functions e.g. in natural language processing for history taking. This is of course all impressive and interesting, but to get a good learning outcome it is often unnecessary. In fact, there are studies published that fail to show any improvement in learning outcomes with growing technical sophistication of the VP simulation [Dankbaar16]. Some features of virtual worlds may actually be more a distraction than help. High technical requirements lead to problems in simulation accessibility (e.g. when external Internet connections are blocked, there is no possibility to install plug-ins or require expensive non-standard computer equipment like VR headsets) [Conradi09]. It might help to be clear from the very beginning that introducing VPs in the curriculum is not about impressing one with technology or entertaining, but about learning what is relevant in clinical reasoning in a flexible and interactive way.

The notion that VPs require dedicated computer labs to implement is nowadays largely outdated. The availability of computers or mobile devices at students' homes is wide-spread. Taking advantage of this is an obvious way when you plan to implement VPs as part of the online preparatory activities in the flipped classroom model. If you need to be available in person for feedback while they are learning, you may suggest a "bring your own device" class when students have one shared laptop for a team brought by a group member. Of course this works only in the case you do not insist on the use of technically sophisticated VP solutions requiring for instance virtual reality headsets or high bandwidth Internet connections as discussed above. But, for instance CASUS, the VP system in use to host the iCoViP collection, requires for execution a plain web browser and works across all common operating system platforms. This is also true for several other VP platforms such as OpenLabyrinth or DecisionSim.

Another way of reducing costs is to collaborate and share both resources and experiences. The history of VPs is full of examples of initiatives in which universities from one or several countries team up to jointly create, repurpose or support themselves in using VPs. Good examples could be projects like CLIPP [Fall05], NetWoRM [Kolb07], eViP [Poulton11], the MEFANET network [Majernik16] and many more. Of course, the iCoViP project in the context of which these guidelines and the VP collection have been developed, being a collaboration of six universities, is also an example of a shared effort. The results of such consortia are often publicly available on the Internet for several years after the project has ended. So, the next tip is to search online for free content and tools. If not found, maybe you can reduce the cost of developing VPs by sharing the effort with partners in a project or network you join.

You can also learn the know-how in a cost-effective way from the experiences of other universities. Dewhurst et al. describe for instance how VPs have been implemented at several universities in Malawi [Dewhurst09]. The key to success was a series of workshops organized by visiting instructors from Scotland for those who just started the use of VPs in Africa. Another example of a long lasting international collaboration is the MEFANET initiative of Czech and Slovak universities who organize regular annual meetings to discuss experience in using e-learning resources, including VPs [Majernik16]. Kolb et al. reported about an international collaboration with many European universities in the area of VPs for occupational medicine [Kolb07]. MedBiquitous is a US-based international organization to support technical standards and good practice in the field of computer-aided medical education [https://www.medbiq.org]. In order to save time and money you should avoid doing repetitive work for example by joining a community that shares the same goals related to VPs as you have.

Some of the work can be completed in collaboration with residents and students who can help in development, translations and integration of VPs with minimal supervision of experts. For instance, in the project NetWoRM LA Students from Germany annually visited partner universities from Latin America (Brasil, Chile) to create VPs in collaboration with local experts. It turned out that those VPs were more interesting and motivating for users than VPs created by teachers [Radon11]. Some iCoViP partners (e.g., Jagiellonian University) collaborated closely with students while developing and translating VPs. This has significantly accelerated the project. For students, collaboration in such initiatives is rewarding as a learning by teaching scenario, an opportunity to collect international experiences and to improve intercultural understanding.

The tools you use to support teaching with VPs - for instance an e-portfolio system, tools for creation of concept maps or discussion boards do not need to be a commercial solution. There are several open source or freely available tools like Cmap, Moodle, Mahara or Padlet in use that can be used to support activities. If you need to enrich the existing VPs with new multimedia instead of developing those from scratch, you can also look for free images and videos under Creative Commons license (e.g. on Flickr) or in low cost stock photography services (e.g. Shutterstock).

Finally, some of those who complain about the costs of VPs forget that the alternative to VPs also costs money, sometimes more than what is required for VPs. As discussed in other parts of this guideline, medical curricula are often already filled to the brim and the introduction of VPs is only possible when some other activities are replaced. The money that is saved by discarding or reducing time in the curriculum of one type of education can be relocated to the new type. Traditional education also requires classrooms and teacher time for preparing and conducting the classes. The advantage of online resources is that after an initial investment to implement the resources, they can be used by many students. VPs have already been used in Massive Open Online Courses (MOOCs) with close to 20.000 enrolled students [Kononowicz15], and with minimal scaling-up costs. You should take into account that alternatives to VP simulation modalities are very expensive. For instance, the time of simulated patients is limited and requires training, salaries and on top of that the experience cannot be shared by many students simultaneously. In another study conducted by Haerling, it was shown that the cost associated with mannequin-based simulation is three times higher than for VPs without difference in terms of improvement in knowledge and satisfaction [Haerling18].

Recommendations:

- Share the effort of developing VPs by collaboration with other universities or reusing free available VPs as the one developed by the iCoViP project.
- Collaborate with residents and students on development of VPs with mutual benefit.
- Some costs are unavoidable while using VPs - like maintenance of the technical infrastructure, technical support and content updates. But you can save money by lowering expectations on rich multimedia and sophisticated technical features with minimal impact on educational outcomes.
- Remember that other teaching methods, alternative to VPs, also cost money that can be saved when you decide to use VPs.

Step III. Goals and objectives

Theme: VP alignment with the curricular learning objectives

Guiding questions:

1. How do I align the VPs with the overarching learning objectives of the curriculum?
2. How do I make selections of the VPs?
3. How do I modify the VPs to adjust them to those goals?

One of the most important developments in medical education of the last two decades is the movement towards Outcome-Based Education (OBE) [Holmboe21]. Curricula designed following this paradigm start with a clear specification of the intended learning outcomes. All the decisions made regarding the curriculum design, in particular selection of the instructional and assessment methods, should be directed towards achieving the pre-specified learning objectives. In order for VPs to contribute to fulfilling the overall course objectives, they need to be "constructively aligned" with those objectives [Edelbring12].

Therefore, when introducing VPs into the curriculum it is very important to first identify the learning objectives (LOs) in the curriculum that are suitable to be addressed with VPs. What those relevant learning objectives are depends on many factors including the mission statement and overarching goals of the curriculum at your university. Some countries may be obliged or strongly recommended to implement specific competency frameworks prescribed by various accreditation bodies. Finally, this may depend on LO-specific disciplines [Radon11]. Do not forget to consider here also the level of competency of your students that you want to introduce the VPs to, or user-specific interests (you can read more about these topics in this section).

The general guideline is to consider VPs as a valid instructional tool to achieve LOs related to clinical reasoning [Cook09], [Plackett22]. VPs come to the rescue when it gets hard to fulfill LOs because of insufficient inpatients covering specific diagnoses. They can work well as an additional learning source in the absence of real patients or clinical teachers, allowing learning to be continued [Tworek10]. However, apart from learning about the management of different diseases, there are also other curricular objectives and themes that may be well implemented with VPs. In particular, these could be cultural competencies [Smith11], sex- and gender-specific health [Casanova19], care for patients with special needs like developmental disabilities [Sanders08], empathic communication with patients [Guetterman19] or interprofessional collaboration skills [Edelbring22].

In an integrated curriculum, VPs can be a useful tool in addressing basic sciences' LOs for higher motivation to learn it in a clinical context. For instance, while presenting VPs to discuss with the students the pathophysiological mechanisms behind common signs and symptoms you should pay attention to the use of adequate semantic qualifiers. This strategy is likely to facilitate better knowledge encapsulation that leads to more robust clinical reasoning [Woods07].

It is also worth emphasizing that VPs are not only suitable for teaching but can also be an assessment method for many LOs [Huwendiek08]. We discuss formative and summative assessment with VPs here. However, we would like to stress here, in particular, that if you address a clinical reasoning LOs (so-called higher level thinking) with VPs and then assess the outcome using a knowledge-based multiple-choice question test alone, you should not be surprised to see modest effects as this is not a good example of constructive alignment. It is important to explicitly communicate to the students how the LOs of your VPs contribute to the overall concept of the curriculum [Hege07]. What may help is to map existing VPs to the end-of-program outcomes highlighting where the curriculum objectives will be met, where there is still an option to enhance the learning, and where there are gaps [Altmiller21].

If you have the opportunity to edit the VPs, you may wish to adapt them to your particular LOs and target levels of competencies. However, you need to be careful not to lose the authenticity of the VPs, meaning that it should closely relate to the work of the practicing health professional. According to Hirumi et al. (2016), simplifying the interactions within the VP case, will decrease the authenticity, but will also reduce frustration and increase satisfaction with the user interface [Hirumi16]. Furthermore, we have discussed localization of VPs in the section on prioritization of VP here.

Based on the literature and our experiences, there is no defined number of VPs you should put into the curriculum. As the different researchers present their findings, clinical reasoning is problem-specific and there is no generalizable problem-solving algorithm that can be learned [Elstein78] [Norman05]. It means that medical students need to experience in the curriculum a large number of cases with a range of specific medical problems to become competent physicians [Lanphear21]. For instance, in one paper, authors have introduced 72 VPs in the renewed curriculum at the University of Toronto [Kulasegaram18]. The iCoViP project collection contains 200 virtual patients [Mayer22]. We underline that the selection of VPs in such collections should be well thought through and should be attempting to resemble the distribution of diseases in the VP collection to that of the target population of real-life patients to avoid introducing bias to the students. The higher the number of cases you have in your collection (more than 15 cases), the higher the mean satisfaction of students will be [Al-Dosari17]. But of course, you should always consider your educational setting, curriculum, and LOs when deciding on the number of VPs.

Recommendations:

- VPs need to be “constructively aligned” with overall course objectives.
- VPs are a tool to achieve LOs related to clinical reasoning.
- VPs are a useful tool in addressing basic sciences’ LOs for higher motivation to learn it in a clinical context.
- VPs can be adapted according to the needs, but keep in mind not to lose authenticity.
- There is no defined number of VPs to be integrated into the curriculum. Students need to experience a large number of cases with a range of specific medical problems to become competent physicians.

Theme: Prioritization/relevance

Guiding questions:

1. Should the use of virtual patients in the curriculum be mandatory or voluntary?
2. How to improve the perceived relevance of virtual patients by students?
3. How to adapt VPs to local needs to make them more relevant to the students?

Integration of virtual patients in curricula differs by the weight the faculty put on their use by students. Some universities tend to play safe and introduce VPs as voluntary activities. Interested students are recommended to use VPs to deepen their knowledge as a self-study in their free time. Other universities make them mandatory which means their completion is a core requirement to obtain course credits. Which of these approaches is better?

There is no simple answer to this question and the evidence for recommendations is limited. What has been consistently observed is that when VPs are completely voluntary their use will be very low [Radon11], [Kim18]. In a study by Hege et al., just around 10% of students used VPs when they were optional [Hege07]. Such behavior of students has been observed in implementation of other types of e-learning and simulation in general as well [Issenberg05].

The straightforward solution is to make the use of VPs obligatory. This is even expected by some students who admit that they need external motivation to complete them [Huwendiek13]. Yet, there is a risk in mandatory integration scenarios. Teachers tend to set completion criteria easy to verify automatically, like minimal percentage of content (e.g. screen cards) displayed, time spent on exercise, success rate in multiple choice questions. But this can lead to superficial learning. There are always students who get tempted to game the system and click mindlessly through the content to reach the required threshold score or exchange answers to questions with other students [Hege07]. Kim et al. compared the mandatory and voluntary use of VPs in clinical clerkship and found that students in the mandatory integration mode completed more VPs and spent more time on them [Kim18]. Unfortunately, there was neither any difference in objectively measured knowledge by the end of the clerkship nor in student satisfaction which might be interpreted as evidence of superficial learning. Within the project consortium we have described different integration scenarios that you might find helpful.

The key to gain educational benefit from VPs seems to be to convince the students about the relevance of VPs to succeed in their health professional career [Edelbring12]. One way to achieve this is to show them explicitly how the learning objectives of VPs map to the curricular learning objectives. This is already discussed here.

Another solution is to take advantage of the rule that assessment drives learning and make the VPs exam-relevant. It means that the use of VPs remains voluntary, but it is explicitly stated how their content is covered in the examination blueprint. For instance, the teacher may declare that 20% of the questions in the final exam will address topics discussed in the VPs. In the study by Hege et al. more than 90% students used exam-relevant VPs [Hege07]. The result was comparable to the obligatory strategy, but the time the students spent on solving the cases was longer and there were indications of a more in depth approach to learning.

There are also other ways to improve the perceived relevance of the cases by students and by that their usage ratio. One of them is to involve students in the authoring of VPs. This approach is known as the “learning by teaching” strategy [Hege07]. Students often know best what is challenging for them in handling VPs and in collaboration with experts in the field focus on those issues when designing cases, learn from that, and make the VPs more relevant for peer students [Radon11].

Motivation to use VPs is low when students think they are not their target group. This may happen when VPs in the curriculum were developed in a context different to that of the students’ - e.g. as presented in external commercial products purchased by the university or in cases by authors from abroad in international projects [Fors09]. Some of the recommended diagnostic and treatment methods may be different and the cultural background feels foreign. The language of the VPs may be a barrier as well. Fors et al. has observed the use of VPs in a group of Romanian students who declared good or very good English skills. The same cases were randomly assigned to students either in English or Romanian language. Despite good declared English skills, students selected more diagnostic tests, made better decisions and spent more time on learning when the cases were available in their mother tongue [Fors09].

The solution to the foreign context problem could be the language and cultural adaptation of VPs when implementing them in the curriculum. Some of the systems allow the content of the VPs to be translated in the native language of the student, which is worth the effort even if students (declare to) have good English skills. Medical tradition and cultural differences can be clarified and commented to the students by local specialists in expert comments connected with the cases. Improving intercultural understanding is important due to the growing mobility of patients and medical doctors and international VPs provide the opportunity to broaden student’s views and experience [Fors09], [Radon11]. The iCoViP project has developed a workflow to handle the adaptation process and applied it in the development process of the 200 VPs initially designed in

English to the local context and language of the 5 participating countries. The collection can be accessed here.

What is also very important in convincing students about the relevance of VPs is the positive attitude of their teachers to the cases. Students are skillful in recognizing that. If the teachers disbelieve in the effectiveness of VPs, so will their students. If the teachers say this is just for the “young generation”, the students will doubt they will get feedback in case of problems and the topics presented in VPs will be relevant during their examinations. It is crucial the teachers walk the way they talk: know the content of VPs, are familiar with how to use them, and make reference to them while teaching.

Recommendations:

- When choosing an integration scenario for your institution, take all the advantages and disadvantages into consideration. Completely voluntary use may meet with low interest. When making VPs obligatory make sure you will not tend to set completion criteria too mechanistic which promote superficial learning.
- Make sure your VPs will be relevant to the learning material. Show the students explicitly how the learning objectives of VPs map to the curricular LO’s.
- Making the VPs exam relevant may help to increase the number of cases completed and promote a more in-depth approach to learning.
- When using VPs created elsewhere (in foreign context), you may adapt their language and cultural background, before implementing them into the curriculum.

Step IV. Educational strategies

Theme: Relation to other learning activities

Guiding questions:

1. What influence should VPs have on other types of learning activities (like lectures, high fidelity simulations, standardized patients, etc.)?
2. How should VPs be influenced by those learning activities?

We will present here the nature and scope of both related and competing curriculum resources that affect the use of VPs and the impact that they have on student learning.

When we think about implementing VPs into our curriculum, we try to consider different options of where or how to use them. Often, the medical or healthcare science curricula are packed with required classes. If the assumption is that the VP should replace some other activity, what should it be? Or, if the assumption is that the VP should be used in combination with some other activity, what should it be and how should this combination look like? If the VP activities and supplementing activities should be presented in a specific order (including time spaces between the activities) what should it be? Below we will try to answer these questions.

Subtheme: Replacement

One of the challenges you may face when introducing VPs into the curriculum is that it cannot be stretched more and some elements will need to be removed to make space for using VPs. But what to choose to not compromise the overall objectives? The current literature reflects this struggle.

If you need to make a decision about removing activities from an existing curriculum to make space for VPs, it is better to replace passive forms of teaching - like lectures or reading exercises - instead of active methods like small group discussions or mannequin-based learning [Kononowicz19]. At the same time some authors remind us that if you uncritically remove some teaching activity, this would not necessarily improve neither the perceived integration nor the learning [Berman09] [Lang13]. With iCoViP partners we discussed that a replacement should not be radical and involve a complete withdrawal of an established teaching format for the benefit of VPs rather it should have the form of a partial replacement. For instance, even though lectures have limitations, they still have their role in introducing key knowledge concepts. Yet, the replacement of static case presentations within lectures with VPs was regarded as a reasonable solution. In our iCoViP project discussion around the guidelines the opinion was often voiced that the beauty of teaching comes from preserving diversity of suitable teaching methods.

If you already work with traditional paper-based cases, there is a recommendation to replace them with virtual cases [Cendan12]. In a study by Poulton et al. the replacement of paper-based cases by online VPs in PBL sessions was highly appreciated by both students and teachers [Poulton09]. It has been shown that students and tutors think that interactive VPs provide a more authentic, immersive experience suited to problem solving [Poulton11]. Furthermore, compared to reading a book, the use of VPs was found to trigger higher student engagement, and having an extra dimension with the use of video clips of patient presentations. VPs are also a valuable tool in terms of time-efficiency compared to real patients' interactions or case seminars as well as variation in learning activities, studying “in a different way” as compared to traditional methods [Edelbring11].

Students also express preference of VPs over traditional knowledge transfer solutions such as lectures [Dahri19] [Kolb07]. When they have a chance to independently work with VPs (e.g instead of going to lectures), they have the opportunity to self-assess their diagnostic and patient management skills [Ellaway11]. According to one of the studies, 78% of students indicated that replacing lectures with virtual patient cases allowed for better use of faculty contact time with them and 84% of them said that completing the virtual patient prior to class allowed them to become better self-directed learners [Benedict13]. Also, it was important to students during clinical clerkships to have some activities removed in order to deal with the additional workload created by the integration of VPs [Huwendiek13].

Choosing to move to VPs could solve problems related to financial constraints on materials [Maleck01]. The paper-based medium itself can put a strain on tutors: lack of accessibility, the cost and time resources to replicate the patient's imaging and other materials needed for the paper-based cases. Thanks to moving to VPs we may improve the delivery of patient cases [Zary09] and save some resources, while still increasing learning opportunities [Doloca16]. As one of our students once summarized about working on a VP module: "you do not have to copy it, and you cannot lose it" [Kononowicz12].

There is also a strong recommendation to never replace real patient contacts with VPs, unless it is absolutely necessary, which for example we have observed during full lockdown because of the COVID-19 pandemic. Yet, this should be regarded more as a short-term emergency solution rather than a real replacement. The same applies to situations where the healthcare setting does not provide a patient matching our learning objectives. VPs could complement areas where there are no other suitable learning tools for clinical reasoning and problem solving [Poulton11]. Moreover, VPs could be a learning tool directed into a specific task [Edelbring11].

In general, when VPs are integrated into existing learning activities or used to replace such activities, the perceived implementation seems to be more successful than when redundant traditional methods are kept in place [Berman09] or when VPs are used as additional activities on top of the existing curriculum [Lang13].

Recommendations:

- When looking for elements in curricula that can be replaced by VPs focus on passive forms of teaching, like static case presentations in lectures.
- VPs can save money and add more flexibility when replacing paper-based cases.
- Do not replace real patient encounters with VPs unless you are forced to do that due to extreme conditions like the COVID-19 pandemic or to fill gaps in the clinical experience due to lack of access to particular clinical presentations.

Subtheme: Extension

Integration/addition/alignment

In this section we will try to focus on situations where we want to introduce VPs as an addition to other, already existing learning activities. What should be the combination and what should it look like?

Any integration process of VPs into the curriculum must be carefully planned, implemented and evaluated. To be successful, e-learning resources like VPs, in particular, must be integrated and aligned with the desired learning objectives [Baumann-Birkbeck17] and other teaching events [Haag10] like cardiac auscultation exercises on mannequins [Quinn11] or radiological course programs [Scherer11]. As stated by Huwendiek et al., those activities should be built on each other to give the students an opportunity to apply newly gained knowledge [Huwendiek13].

VPs can be used in very different settings. Cases can be included in all learning environments being particularly suitable to small groups, larger interactive classroom teaching sessions and individual learning. VP cases can be used as a prerequisite for high-fidelity simulations [Singh03] or may be used as an assessment method of intended learning outcomes.

Students themselves prefer to have the VPs introduced after rather than during the lectures, which they call “an incompatible setting” for the experience of working through cases [Dahri19]. It is possible to combine communication-focused classes or mannequin-based activities with the use of VPs by asking students to solve cases in preparation for high-fidelity simulation. When students are waiting to take their turn on a simulator or enter a role playing activity, give them a VP case to solve, which will allow them to stay active and focused throughout that time. Thereby, you can use the existing resources in a better way, enhance different experiences and turn partial-task training into whole-task training [Ellaway15].

As noted by Fischer et al., if we use VPs without integrating them into the curriculum, this would lead to low acceptance of such methods. Therefore, exam-relevance of VPs and integration with follow-up seminars are key factors for a high level of acceptance. Fischer et al. presented an example from Munich where internal medicine learning cases ceased to be integrated on a mandatory basis. Instead, students were provided with 15 learning cases that thematically related to a weekly seminar (with 18 students per group) and dealt with content that was relevant to the final written exam. The learning cases were to be worked on in self-study as preparation for the follow-up seminar and discussed there. About 10% of the questions in the final exam referred to case contents [Fischer08].

VPs can also be an addition to simulated patients (SPs). As stated by Cendan et al. 2012, this solution gives the students the chance to revise the content, to receive individualized feedback, to reflect on the actions taken during the encounter, and to compare their decisions with the best practices protocols or recommended procedures. VPs can be used, for instance, in a situation where the SP cannot demonstrate some of the elements of physical examination findings like cardiac murmurs, abnormal breath sounds, or neurological deficits [Cendan12], [Johnson13]. They can also be used as preparation before either interacting with an SP, where the given feedback might potentially be a powerful educational tool [Stevens06], or with real patients, which can give students more confidence. More about feedback will be covered in this section.

In the literature, recommendations can be found on using VPs alongside traditional clinical placements [Menendez15]. There is a strong notion that it should complement the bed-side teaching, making it more understandable and meaningful [Edelbring11] and also allowing to link the basic sciences with clinical encounters [Posel12]. iCoViP partners recommend that VP activities can be given to students during clinical placements when doctors are for important reasons unable to take care of students. The lack of availability of patients showing a particular clinical presentation during the clerkship can be compensated by a VP experience as suggested by the Liaison Committee on Medical Education (LCME) ED-2 standard [Tworek10]. For instance, it can be used on the last day of the clerkship if there are gaps (VP is better than nothing), or in times when clinical teaching and learning is temporarily impossible (i.e.: during the COVID-19 pandemic) [Nascimento21].

When we speak about the relation to other learning activities, a relevant component of VPs integration is to organize a follow-up seminar around this activity. According to Zary et al., teacher-led seminars may still play an important role in providing credibility to the VPs [Zary09]. Further advantages are that it gives higher effectiveness for learning in terms of deeper discussion within a safe environment, seems to catalyze the case processing and relates the cases to the clinical reality by virtue of the teacher's clinical perspective [Edelbring12].

Recommendations:

- Use VPs to integrate core knowledge concepts presented in lectures.
- VPs can be used in preparations for simulation classes.
- During clinical placements, VPs can be used to fill in gaps caused by lack of availability of patients with specific clinical presentations and in case of limited time of clinical teachers.

Subtheme: Sequencing

When you are considering implementation of the VPs in relation to other learning activities, one more factor should be taken into account. It is how we will sequence the VPs with other teaching events. Should they be presented in a specific order (including time spaces between the activities), and what could it be?

Most importantly, try to be flexible in sequencing VPs depending on your needs and the needs of your students, as well as the learning objectives you would like to achieve. It was found that spaced activation contributed to a more balanced (spread in time) use of VPs with a lower peak of number of sessions right before the exam [Maier13].

If you are considering using the VPs with lectures, you could introduce them before the lecture to activate students' knowledge; or after - to reinforce it. For instance, in the study of Huwendiek et al. 2013 students preferred working on VPs after the lectures, as it enabled them to apply knowledge from the lecture to the VP. This had another function, it raised students' confidence and helped them memorize important aspects [Huwendiek13]. According to the majority of students (78%), completing the VPs before the class gives an opportunity to use the class time for activities more difficult to complete at distance as hands-on-training or small group discussion, and therefore it stimulates self-directed learning [Baumann-Birkbeck17].

In the case of bedside teaching, VPs can be used also in two ways: before meeting a real patient - to gain confidence; or after - for reflection or to discuss errors. As noted by Huwendiek et al. 2013, according to students, it was highly meaningful, motivating and supportive for their learning to work on a VP before an encounter with a real patient with similar symptoms. This made them feel ready and confident to engage in these encounters. Students can plan which questions to ask, what kind of examinations to perform and which differential diagnoses to take into consideration [Huwendiek13].

What also may be beneficial, is to let the students work on VPs independently at home, so they can develop their problem-solving skills, and then follow it up with a tutorial with the teacher, where students can sum up their learning, revisit the case, as well as get answers to all of the questions, that may have arisen. Between these two meetings, interdisciplinary lectures use the case as a springboard to cover relevant concepts [Kulasegaram18]. Riedel et al. 2003 found that the scenario where first students work in a group of 2-3 per one computer, with the tutor present in the class, and then learn alone at home - was assessed as the best implementation method [Riedel03]. There is also another aspect of organizing small group discussions after individual work with VPs. It was found that students take such a solution more seriously, when they know that they are likely to be questioned about the VPs [Huwendiek13].

Most probably, there is no one best solution in terms of sequencing when using the VPs. Generally, it is believed that if you sequence a lecture, followed by one or two VPs, then organize a small group discussion and finalize with a real patient encounter, this will give a student maximum support for their learning and optimal preparation [Huwendiek13]. Similar recommendation was given by Hirumi et al. 2016 where the integration strategy included a lecture, a demonstration of NERVE [a digital learning environment around cranial nerve disorders knowledge] with explicit expectations and requirements, VPs interactions within the NERVE, an instructor-led AAR [After Action Review, i.e. follow-up seminar] with the entire class, and a standardized patient/virtual patient (SP/VP) hybrid encounter [Hirumi16].

Recommendations:

- The most common sequence in the use of VPs is: start with lectures, followed by VPs, small group discussion and end with bed-side teaching.
- When presenting VPs to students, activate them one at a time with a time gap between them and do not make them available all at once. This will result in a more balanced use of VPs.

Theme: Learning activities around VPs

Guiding question:

1. What should be the tasks students are supposed to do around virtual patients?

Virtual patients are a great tool to learn clinical reasoning. During the design and integration process different types of activities should be taken into consideration, to allow a meaningful and engaging learning process.

Ellaway and Davies distinguish the following learning activities around the VPs: read unfolding narrative, select appropriate history questions, select management options, make diagnosis, learn underlying medical science through guided discovery (optional), view report and debrief (if logged in) [Ellaway11]. Other tasks could be writing a summary statement, creating a concept map, creating a case (learning by teaching strategy), solving a case in an interprofessional team and group discussion.

For example in the CASUS system students are asked to fill in a summary statement, a short presentation of a patient of usually one to three sentences length. It is a synopsis of findings from history taking and physical examination. The ability to present a patient in such a concise way is a good indicator for clinical reasoning skills, because the student has to summarize and synthesize a patient's information [Bowen06]. This also provides a chance to practice clinical semantics [Posel15]. Summary statements can be required any time during the case, but they are particularly relevant for case completion. If the author includes examples of expert summary statements as model examples for students, these can be used to scaffold learning, isolate gaps in domain knowledge and as a powerful tool for formative or summative assessment [Posel15].

Important element of VPs cases are concept maps created by students during the process of working on the case. A concept map is a graphical tool for organizing knowledge and it results in a visible representation of the students' clinical reasoning on a case, which permits them to identify learning gaps [Penuela-Epalza19]. Learning with a use of concept maps creation allows combining lower order concepts with higher order concepts, which then can lead to formation of a hierarchy of knowledge and understanding [Daley16].

Another activity to be used around the VPs is to involve students in the creation of the cases. Learners show a positive and highly motivated attitude towards this teaching strategy. In a paper by Hege et al. motivation was attributed in 67% of the students to the interest in case-based training and the effectiveness of this strategy [Hege07].

VPs can be also used in activities of interprofessional groups of students. Such a solution allows better understanding of the other profession's scope of practice, tasks and responsibilities. Furthermore, it provides a holistic patient's perspective through the complementary professional view [Edelbring22]. Solving VPs in mixed teams promotes interprofessional teamwork and collaboration. They can share their ideas, decision making and responsibility, which in overall prepares them to work in such clinical teams in real life [Martini19].

As noted by researchers one of the tasks could be also a discussion, where students are comparing two VPs with common differential diagnoses or a combination of similar, but contrasting VPs, where the students are encouraged to consider alternative diagnoses and reflect on key features of each of the VP cases. This improved students' understanding of disease and helped reflect on differential diagnoses [Cendan12], [Huwendiek13].

Recommendations:

- Adding summary statements as a task allows students to learn how to in a concise manner present findings from history taking and physical examination and is a good indicator of clinical reasoning skills.
- Learning with the use of concept map creation gives students the opportunity to organize information in complex VPs and demonstrate an understanding of the relationships between clinical findings and diagnostic hypotheses.
- Other activities could be creation of the cases by students, working on VPs in interprofessional teams, and discussion on similar but contrasting VPs.

Step V. Implementation

Theme: Time allocation

Guiding question:

1. How much time should the students have for VPs activities?
2. Should time for VPs be regulated at all?

The problem of time allocation is interconnected with all the previous themes. The literature strongly recommends that students should have adequate time allocated to work on VPs, because this is an overall important aspect when integrating e-learning into the curriculum [Edelbring11], [Hege07]. In this section, we will discuss what can be considered an “adequate” time.

Generally, the time used for case completion will be dependent on the type of learning objectives (e.g. emergency medicine may need different time allocation than psychiatry), but also on the stage of the study programme (more time will be needed in the beginning of the curriculum and less towards the end). Some research indicates that time used for interacting with the system varies a lot, the majority of students access the system the day before a seminar (AAR) and SP/VPs encounter, and just a few went beyond specified minimum requirements [Hirumi16]. If a VPs panel is used with a few clinical cases to be solved, tutors should recommend the students not to accumulate work on the last day before the deadline, but divide it equally in time.

According to the literature, students appreciate dedicated time for self-study with VPs as they can work at their own pace with each case [Huwendiek13], [Radon11]. Despite some of the VPs being designed to be completed within 45 min (one academic hour), a wide range of time spent on working on the cases was observed. In the study by Dahri et al. (2019), year 3 students perceived 60 min of time to be inadequate and year 1 and 2 indicated 90 min allocated for the case work to be adequate [Dahri19]. On the other hand, students during clerkships spent 15-20 hours, completing around 20 CLIPP cases [Berman11]. A study by Hege et al. tested different integration scenarios of VPs and showed that students spent less time in mandatory than exam relevant VPs [Hege07]. Similar results were observed in another study where students spent approximately 15 minutes on one VP [Kononowicz12]. Based on our experiences from an iCoViP pilot, time for case solving should not be restricted if students are working at home, but it will be helpful in class to better control it. If you would like to assess how much time students spend on each case, learning analytics (LA) can be used.

Time will play an important role also during the exams. Students who took the exams on a VP without time constraints used approximately twice as much time as students with the time limit. This first group utilized half as many inquiries of the patient history, physical examination, and lab/imaging tests than were used by students from a second group, indicating that the time-constrained students used a 'shotgun approach' to try to collect as many 'required' inquiries as possible. Interestingly, in terms of obtaining the correct diagnosis, the majority of the students (91%) who took the untimed exam were successful, but of those with the time limit, only one-third (31%) correctly diagnosed the VP exam case, despite their higher number of queries [Gunning12].

When preparing to incorporate such activities like VPs into the teaching, it is crucial to consider also how much time and effort faculty need to invest to support a case-based course and whether this is feasible [Hege07], [Nagji20]. Students would like to get feedback on their performance which often cannot be completely automated. The curricula with VPs have to be updated and modified, and this may take a substantial amount of teachers’ time that should be rewarded [Radon11].

Recommendations:

- Time used for case completion will vary and will be dependent on the type of learning objectives and stage of the study programme (more time will be needed at the beginning, and less in higher years).
- You should not restrict the time for students when they work at home, but give them limited time, when working on the cases in class.
- Students perform better during untimed exams. Number of correct diagnoses during a time limited exam is lower than in an untimed one, despite their higher number of queries.

Theme: Group learning setting

Guiding questions:

1. Should students work individually on VPs or in groups?
2. If in groups, how large should the groups be?
3. If in groups, what should be the group composition?

Interaction is key when learning clinical reasoning using VPs. Some students appreciate discussing VPs with their peers and teachers [Nagji20], whereas some prefer to interact with the technology while working with VPs individually. Both scenarios are possible in VPs [Edelbring12] and based on our experiences it will depend on the purpose of VPs and learner's preferences. In some settings, self-directed individual learning might be necessary because of limited opportunities for small-group learning [Johnson14]. Yet, there are many advantages of working in small groups. In fact, a meta-analysis of 122 studies (not limited to VPs) found that collaborative learning is more effective on several cognitive, process and affective outcomes in diverse disciplines like health, math or physics, than individual learning [Lou01]. Furthermore, working in small groups enables open discussion in a supportive learning environment [Naumann16]. Students who solved VPs in teams achieved significantly greater learning gains, better diagnosed cranial nerve palsies and were more satisfied than students working individually [Johnson13], [Johnson14]. Also, Cendan et al. found that students in a group of 3 learn more compared to those working with VPs individually. They hypothesized that this performance improvement was related to a lower cognitive load effect on the group users [Cendan12]. Working in groups fosters skills in clinical reasoning, but also in team collaboration [Naumann16], allowing the application of cooperative learning strategies [Huwendiek08]. The VPs designed for group work can be of lower complexity since the reflection and reasoning will come from the interaction inside of the collaborative working experience [Edelbring11], [Ellaway15].

Regarding group sizes, even though there are examples of the use of VPs in large groups like lectures [Hooper15], smaller groups are advised as they increase the exposure of each student to VPs and impose greater responsibility on each student [Edelbring12]. The literature does not specifically define "small groups". According to Edelbring et al., students felt that working in pairs broadened their reasoning the most when compared to individual and larger groups [Edelbring11]. Poulton et al. report that the use of VPs in digital problem-based learning sessions with 6-8 students was accompanied by good performance improvement outcomes [Poulton14]. The pilot implementations within the iCoViP consortium showed that the groups were composed of 2-5 students, but mostly 3-4. The groups were bigger when VPs were used in class. Facing the lack of clear preferences in the literature, we recommend adjusting the decision to local settings.

We did not find firm evidence on how the group composition in student groups working on VPs should look like. Johnson et al. hypothesize, based on Vygotsky's *Zone of proximal development* theory, that groups should contain a balanced mix of high and low-performing students [Johnson14]. Those struggling with the tasks would be supported in learning by better performing ones. This is indirectly confirmed by their observations that students who had scored low in pretests benefited more from working in teams on VPs than from working individually [Johnson13], [Johnson14]. Another opportunity that comes from working on VPs in teams with specified roles is the development of interprofessional collaboration skills. The feasibility and educational gains of such educational scenarios in teams consisting of medical, nursing, pharmacy, physical and occupational therapy students have been demonstrated in several studies [Shoemaker15], [Martini19], [Edelbring22].

In summary, we would like to encourage the use of VPs by students for small group learning, but at the same time notice that VPs are flexible enough to be used in various scenarios including individual work in self-study scenarios.

Recommendations:

- Students who solved VPs in groups achieve significantly greater learning gains, diagnose better and are more satisfied than students working individually.
- When working with VPs smaller groups are advised more, than bigger groups, but the specific number of participants varies from 2-8 students.
- In terms of group composition you can be flexible depending on your needs and possibilities.

Theme: Presence mode

(F2F vs online, blended strategies)

Guiding question:

1. Should students work on VPs in a computer lab, shared space, seminar room or at homes?
2. If working at distance should it be synchronous or asynchronous?
3. If a mix of those modes is recommended what should guide the selection of the mode?

When preparing integration of VPs into the curriculum, another important aspect to consider is the presence mode, namely what are the differences (and potential advantages and disadvantages) between working on the VPs on-line or in-person, during classes or using a blended strategy.

In face-to-face settings, students physically are present on the campus to work on the VPs. One of the advantages of this approach is for participants to get to know the computer program they intend to use, for the teacher to introduce important or complex topics [Fischer08]. Also specialized solutions such as VPs in virtual reality or in combination with other forms of simulation (e.g., standardized patient, patient simulator etc.) can be implemented that way. Solving VPs cases in the presence of a tutor gives the students higher motivation, especially when content is related to the exam material [Hege07], and less distraction when they work the VP cases in the classroom. Students also can receive immediate feedback or guidance when encountering problems during case solving. In interprofessional groups, the learners appreciate face-to-face form as an efficient tool to enrich the discussion and get a meaningful value in the encounter with the other profession [Edelbring 22]. In the literature, different formats are indicated, depending on the level of curriculum, rooms availability etc. VPs can be introduced as an individual or group laboratory exercise.

Regarding the on-line setting, working on the cases at home allows for self-directed learning at the student's own pace, and deeper reflection on the material covered during small-group practicals [Riedel03]. Depending on the learner's needs, students can fill in their own knowledge gaps (by reading additional resources) and organize their thoughts (e.g. in the form of a concept map); in this way, learning can be personalized, related to the individual needs rather than the needs of the group. The on-line setting can also be used in situations of limited access to learning spaces or restrictions on contact hours [Johnson14] as happened during the COVID-19 pandemic or during individual illness, family situation, course of study or more logistic-based problems like conflicts in the study programs for interprofessional training. In this case students prefer an on-line encounter due to flexibility in time and space [Edelbring 22].

If you are just starting with an on-line learning environment, we need to bear in mind that getting the tutors trained will take some time and this strategy might not be readily available. You can read more about teachers' training in this section.

A compromise that combines the above techniques is blended learning. VPs may be featured in both face-to-face, synchronous online (collaborative) and asynchronous online (independent study) elements of an activity [Ellaway15]. VPs can aid the delivery of additional content or introduction of a new material in an asynchronous way [Geha18]. It has also proven to be a successful theoretical, but practice-oriented preparation before practical implementation of the acquired knowledge (also known as flipped-classroom) [Huwendiek08], which allows students to learn in an environment similar to real practice, reducing the stress and a "culture shock" between university and clinical setting [Morrissey14]. Blended learning using VPs, however, can also proceed first in face-to-face mode - e.g. during a problem-based learning session - and then on-line as a repetition before an exam or as a reflection after an in-person encounter. It was shown by Kononowicz et al. that students using VPs together with face-to-face sessions were able to gain more from the course and scored better in the knowledge post-test than the control group [Kononowicz12].

There is a recommendation that the new curricula should include VPs, because of their utility in distributed learning environments as well as their ability to meet learners' requirements for asynchronous as well as synchronous on-line learning [Posel12]. According to Ellaway et al. (2015), VPs have been successfully used as the integrating or scaffolding medium for distributed teaching. In that case, different groups at different sites work first independently, and then come together for collaborative VPs tasks [Ellaway15].

The conclusion is that face-to-face and on-line modes can be flexibly and consciously selected according to the learning objectives and teaching constraints. Depending on the year of the study you can use VPs in more of an asynchronous teaching, as students will be more experienced and are expected to be more autonomous.

Recommendations:

- Using VPs in a face-to-face setting gives an opportunity to introduce the tool, to have immediate teacher's feedback and tends to be less distracting and more motivating for students.
- Working with VPs in an on-line setting allows a self-directed learning and deeper reflection. It is a solution for limited room availability or other restrictions.
- VPs can be also implemented in blended format, when introducing new concepts, delivering additional material, before the exam or clinical encounter, combining pros and cons of both modes, and bringing opportunity for better knowledge acquisition.

Theme: VP orientation & training

Subtheme: Student orientation

Guiding question:

1. Is user training on the technology/pedagogy of VPs necessary and if so how should it be performed?

To successfully implement a new learning activity or a tool into the curriculum it is important to identify, discuss, and reflect on both students' and faculty's expectations and preconceived notions [Nordquist12]. Guiding students on the VPs prior to the encounter is necessary and may have a direct positive effect on perceived learning [Berman09], [Nordquist12]. Moreover, as some students may struggle with the technology associated with VPs learning platforms, it is vital to guide them through those systems, to avoid distraction from the actual learning experience [Naumann16]. What we have noticed in our iCoViP pilots is that when students received prior training on the VP program they could focus better on the learning process, and not on technical issues.

Familiarization with the VP system and with the concept of VPs should take place upon the first exposure to the cases, for instance with the use of an introductory presentation. During initial demonstration of the system, students can be given a patient monitoring form to aid the systematic collection and processing of information or tutor instructions [Dahri19], [Hirumi16]. Orientation and training on VPs can also be done as near-peer teaching (i.e. postgraduate trainees) allowing active engagement of both parties [Kulasegaram18].

What also might be helpful during orientation process, is to use the student information system, online platforms or course handbooks, to post requirements, instructions (written or video tutorials) or send reminders about the due assignments [Hirumi16], [Nasir17]. Students find it very important to know how the VPs were integrated in the curriculum and aligned with other educational activities. Hand-outs and/or an online timetable, with links to related VPs could be very helpful [Huwendiek13].

Recommendations:

- User training is crucial in order for students to focus on the learning process, rather than technical issues.
- Familiarization with the VP system and with the concept of VPs should take place upon the first exposure to the cases, for instance with use of an introductory presentation.
- During the orientation process use the student information systems, online platforms or course handbooks, to post requirements, instructions (written or video tutorials) and send reminders about the due assignments.

Subtheme: Faculty development

Guiding questions:

1. Why is faculty development on the use of VPs needed?
2. How to buy-in staff to participate in faculty development?
3. How to effectively train faculty in using VPs?

The reviewed literature is unanimous in the recommendation that faculty development is a crucial factor in a successful curricular implementation of VPs (e.g. [Berman09], Haag10], [Kleinheksel17]). It is in general true that each curriculum renewal requires faculty development [Kulasegaram18], but we can also give more specific reasons to justify that for VP faculty training. Contemporary teachers have seen in their lives thousands of lectures, but just a handful of VPs (if any at all) [Posel12]. Sometimes these are not the technical skills that are lacking. For instance, Dafli et al. 2019 showed in her study that the majority of surveyed teachers (~80%) felt their IT skills were sufficient to author VPs [Dafli19]. The point is that the teachers should also know the learning activities around the VPs and how to assess and provide the students with feedback based on those activities. Teachers sometimes blame the new method for the educational failure, whereas the problem lies in their lack of proficiency in the application of the method [Nordquist12]. Lack of a sufficient number of adequately trained tutors makes many VP implementation scenarios infeasible [Hege07]. Therefore it is very important to support and prepare them for this challenge by providing instructions, necessary additional materials, contact details to a help desk or person responsible for technical support.

Teachers are often reluctant to participate in faculty development activities giving many reasons [Sudacka21]. Success depends on finding a good buy-in for the teachers' participation [Kulasegaram18]. Top-down methods require that educators feel that their effort in developing their teaching skills will be acknowledged by their supervisors [Posel12]. This can be achieved for instance by awarding them with additional credit points or certificates recognized in their evaluation. Faculty can be also motivated by their students who expect their teachers to be familiar with the VPs integrated in the curriculum [Huwendiek13] and may express this in negative teacher evaluation. Academic teachers are often also researchers, so they expect to be presented with some evidence that the new method works [Nordquist12], [Posel12]. Finally, it is motivational for teachers to participate in faculty development if the courses are tailored to their individual needs ("learner-centered" faculty development) [Kulasegaram18]. What emerges from our project's pilots is that ideally this issue should be solved on an institutional level. We can also share success stories from the students to motivate teachers. It is feasible to gather people that are involved in a particular course where you want to implement VPs and during the introduction meeting give them a short training from the technical and pedagogical possibilities of the tool.

There is only limited research published so far on how to effectively train faculty in using VPs. Teachers are often highly experienced in their medical fields, but when it comes to the use of new educational methods like VPs, they shift from experts to novices which makes them feel insecure [Nordquist12]. Therefore, their clinical experience should be acknowledged in the training, and it also helps when the facilitators who conduct faculty development courses are valued in the local setting [Gillham15]. Since teachers are often very busy and complain about lack of time for faculty development, it is recommended to offer them a spectrum of short courses that target particular skills from which they can select those that meet their particular task in the curriculum (e.g., case author, small-group facilitator, assessor). This will also give them the possibility to effectively refresh their skills when needed [Kulasegaram18]. Teachers also have their preferences regarding the faculty development method: e.g., some prefer face-to-face workshops close to their workplace, webinars in the evenings, or e-learning modules that need to be accommodated [Kulasegaram18]. An international collaboration of teachers from Scotland and Malawi demonstrated a successful curricular implementation of VPs with faculty development as the key enabling factor [Dewhurst09]. It consisted of a series of three closely supervised workshops in which faculty members first developed VPs in small groups. Next, they discussed how to implement those in their teaching. Less formal approaches to faculty development involve building communities of practice where the teachers can post messages when instant feedback is needed [Steinert21]. Our project partners also give the teachers a chance to get directly involved in VPs creation, which then makes them feel more confident about using such cases.

We should always remember that the technology behind VPs is just one of many factors when implementing them in curriculum. The success of implementation often hinges on human factors. Teachers are the key stakeholders that need to be convinced on the utility of VPs and adequately prepared. Faculty development events are a good opportunity to do that.

Recommendations:

- It is very important to support and prepare teachers for use of VPs in their classes, especially when they are lacking technical proficiency by providing instructions, necessary additional materials, contact details to a help desk or person responsible for technical support.
- Teachers will need good buy-in to actively participate in implementation of a new method. Consider extra credit points, certificates, other forms of recognition in their annual evaluation or share the success stories from the students in order to motivate the tutors.
- Offer the teachers a spectrum of different training methods e.g short face-to-face workshops close to their workplace, webinars in the evenings, or e-learning modules, that target particular skills from which they can select those that meet their needs.

Theme: Technical infrastructure

Guiding questions:

1. What are the technical requirements for a successful integration of VPs in the curriculum?
2. What are the benefits of connecting VPs with other e-learning tools?
3. How to make the technical costs of VPs manageable?

VPs require a technical infrastructure to function. Most of the currently available VPs are accessed using a standard web browser. This does not require much configuration by the learner. However, it is crucial that the VP server is available at all times [Huwendiek13]. This means there should be a technical maintenance team employed with a quick response in case problems occur and a help desk for questions. Unfortunately, services like that require substantial and stable funding [Berman11], [Huwendiek08], [Radon11].

It has been observed that learners tend to complete their VP assignments shortly before the deadlines [Hege07]. For instance, Hirumi et al reported 70% of students worked on VPs in the last two days before the task was due [Hirumi16]. This uneven distribution of workload may influence the performance of the IT system or even lead to system failure. There are two potential solutions to this problem. One is to divide VP tasks in smaller assignments which are space activated [Hege16]. The second is to provide a technical infrastructure that, instead of using one central server, is distributed on several smaller computers forming a cloud of smaller servers that could be turned on or off depending on the number of students. Such solutions are able to endure even very high loads as in MOOC courses [Kononowicz15].

Another technical aspect expected by students is the usability of the VPs. The navigation should be intuitive and the graphical layout should help to focus on the tasks in the VP assignment [Boeker06]. Issues with user-friendliness can be avoided to a certain degree by constantly paying attention to the stakeholder perspective. This can be achieved by frequent needs assessments, following usability guidelines [Kononowicz17] and principles of multimedia learning [Mayer10], involving students and teachers in frequent user experience testing [Nunnally16] and providing technical help and instructions to students while learning [Nagji20].

VPs should not be isolated from other e-learning tools the students use. For instance, it is possible to use one central login/password to access VPs and the learning management system (e.g. Moodle). Next, links to VPs could be part of the learning units in regular courses taught at the university. Furthermore, It is possible to make automatic transfers of scores collected by students in assignments between systems. Another option is that certificates from completed VPs could be stored in e-Portfolio systems. To achieve software integration, there are technical specifications (like Shibboleth, LTI, xAPI) [Kononowicz17] implemented by VP system developers and communities (like MedBiquitous) that work to establish or extend data exchange standards in medical education. To access the iCoViP collection check whether your university is part of the EduGain programme (many European universities are) to enable your students to login using their standard university account. Some of the iCoViP partners add links to iCoViP VPs into their learning management system Moodle using the External Tool function (LTI) which saves a separate login and password as well.

Finally, to make the VPs affordable and in the long term sustainable, it is recommended to share costs by joining consortia of several institutions with one technical infrastructure [Berman11]. This decreases the costs substantially. Several national and international projects demonstrated that it is possible - like the CLIPP project [Berman09], or MEFANET [Majernik16]. More about sustainability and maintenance of VPs can be read in this section.

Recommendations:

- When introducing VPs in the curriculum you will require a technical help desk that reacts in case of disruption in the system operation and supports the students and teachers when questions arise.
- It is possible to save the students the burden of generating another account to access their VPs by using integration technologies that enable login using the standard university account.
- Usability is an important factor in acceptance of VPs in curriculum that requires frequent evaluation and refinements.

Step VI. Evaluation and feedback

Theme: Sustainability, maintenance and quality assurance

Guiding questions:

1. How to sustain the use of VPs?
2. How to update VPs in the curriculum?
3. How to evaluate the quality of VPs?

Development of VPs collections and their implementation are often supported by grants. However, even the most successful projects have to face the moment when the source of funding drains out and new ways of sustaining the initiative are needed. To keep an initiative alive for a long time was never an easy task and the methods depend on the setting. However, there are some that turned out to be successful.

One of such approaches is relying on collaboration across institutions [Berman11]. It was often observed that universities suffer from the non-invented-here syndrome and insist on developing and maintaining their VPs by themselves [Casanova19]. In the long run, the costs are difficult to meet, but when divided across many partners become affordable. Sometimes, payment of a subscription fee by users of the VP collection might be required to cover the basic needs [Berman11].

It is important that the group of users develop a sense of ownership and feel responsible for its content. This can be implemented by establishing an editorial board that consists of stakeholders (e.g., directors of clerkships) [Berman11] interested in the use of VPs at the university. It also helps to align the collection with current national or university learning objectives catalogs [Altmiller22] as well as with changes in the professional practice [Morrissey14] and modify the content accordingly. For instance, the COVID-19 pandemic introduced several changes in the clinical reasoning process and hospital practice and consequently required an update of an existing collection of VPs as was described by Hege et al. [Hege20]. The VP system should enable evolution and end-user customization of the cases [Botezatu10B] and empower the teachers to do the update by themselves if they wish to [Zary09].

For a sustained long-term use of VPs, the collection needs to reach a critical mass of users [Kolb]. It has to be tightly integrated into the mainstream curriculum because sidetrack add-ons usually do not survive [Casanova19]. Leaders at universities must emphasize the importance of VPs and their lasting support [Djukic12]. A VP integration also requires time to be established and mature. For instance Kolb et al. in retrospect judged that a 3-year period of the NetWoRM project was perhaps insufficient for successful implementation of the VPs in all centers [Kolb09].

Finally, a sustainable use of VPs requires accountability [Botezatu10B]. There should be a mechanism to report feedback. Even the unsuccessful uses and less favorable events should be analyzed and conclusions drawn. Feedback can be collected using established or self-developed questionnaires. On the one hand, established tools usually are better validated and permit the results to be compared across different implementations. On the other hand, homegrown surveys can be tailored to the local needs. In the category of ready questionnaires, the eViP project has proposed two VP evaluation tools which were later on further developed and validated by Huwendiek and colleagues. One of them is a tool to measure the quality of VP for the purpose of fostering clinical reasoning [Huwendiek15]. The other is a set of tools to evaluate the quality of VP curricular integration: a student questionnaire and reviewer checklist [Huwendiek09]. These tools have been adopted by iCoViP and are now available on our website together with the results of the pilot evaluations.

Sobocan and Klemenc-Ketis developed a psychometric tool to measure acceptability and attitudes of medical students towards the use of the VPs in the classroom [Sobocan16]. Last but not least, Kleinheksel and Ritzhauptand developed an instrument to measure the adoption and integration of VPs in nursing education [Kleinheksel17].

Besides questionnaires, it is also possible to use observational studies (ethnographic approach) to evaluate how students in small groups interact with VPs [Kulasegaram18], [Edelbring18]. When collecting verbal feedback on the VP use, Hirumi et al. suggest to first ask the students what went well in the VP before addressing problems. This helps in directing students' emotions in a positive manner [Hirumi16]. Formal usability studies may involve professional human-machine-interactions tools as eye movement trackers [Boeker06], [Stevens06]. It is also possible to analyze user activities based on VP system logs. This was described in more detail in the section on learning analytics. Lastly, it is of course possible to organize formal studies to explore the effectiveness of VPs in reaching desired learning outcomes in comparison to alternative methods (e.g. simulated patients, human patient simulators) or different VP design or implementation variants. Such evaluation may follow even a randomized controlled trial study and be published as research studies. Kononowicz et al. recently published a systematic review with meta-analysis of such studies [Kononowicz19]. When you intend to advance your evaluation to the level of a research study do not forget to seek permission of an ethical review board.

Recommendations:

- Encourage your colleagues to support you in sustaining the use of VPs by giving them a sense of ownership of the collection. Invite them to voice their opinion on the quality and let them co-decide on the development of the integration in a VP editorial board or special task force.
- You may save time to evaluate the quality of VPs by using questionnaires available on the iCoViP project website.
- Even if the response rate to evaluation questionnaires is low, you may still use VP systems logs to detect quality problems.

Theme: Assessment

Subtheme: Formative assessment and feedback

Guiding question:

1. What does formative assessment with VPs look like?
2. What are the different forms of feedback that can be given to learners as part of VP?
3. Are teachers needed in formative assessment of VP activities?

There are several formats of formative assessment related to VPs and to activities performed in their context. The basic assessment of performance in VPs is diagnostic accuracy which is the agreement of the diagnosis selected by the student with that of the VP author. Diagnostic efficiency can be defined as the number of (correctly) selected diagnoses divided by the time needed for the task [Braun19]. Also important but less exposed in literature is therapeutic accuracy meaning the selection of adequate management of the VP [Tausendfreund22]. The task of diagnosis can be divided into domains of the clinical reasoning process that can be assessed separately [Plackett22]. Basic knowledge relevant for diagnosis embedded in VPs can be tested with multiple choice questions. Furthermore, assessed can be the recall (did the student notice relevant information) and precision (ratio of non-relevant information) of selected case - e.g. observed clinical findings, asked questions in history taking, selected diagnostic tests. Another possibility is to look into summary statements written by the students for the skills of problem representation and the use of appropriate medical language [Hege20]. Formative assessment is more likely to require the student to provide open-ended elaborations which makes it easier for the teacher to provide feedback. This is different to summative assessment that requires clear-cut decisions that can be reliably marked with a numerical score.

Students using VPs expect and appreciate opportunities for formative assessment and related feedback [Posel15]. This should come without surprise as case exposure does not by itself lead directly to learning and students need guidance on making sense of their experiences [Edelbring11]. There are also studies showing that engagement in formative assessment in VPs is positively correlated with results of summative assessment [Seagrave22].

Feedback regarding activities in VPs can be either automatic (i.e. computer-based pre-programmed) or teacher-led (e.g., in follow-up seminars) [Zary09]. Automated feedback has the strength to be immediate which is often not possible with clinical teachers in a busy workplace [Naumann16] or with simulated patients [Stevens06]. Even though adding feedback to the VPs costs extra time, the effort pays off. As demonstrated in a study by Zary et al. students select VPs that are marked as containing feedback more frequently and engage with them on a deeper level (e.g. provide elaborate answers instead of using the cases merely as source of medical data) than those without it [Zary09].

There are various forms of automatic feedback a VPs can provide. Static [Sailer22] or neutral [Zary09] feedback is the display of expert opinion leaving the comparison of provided answers to the student. Constructive feedback is a checklist that matches and compares student answers to the expert recommendations [Zary09]. Students appreciate it by the end of the session as it clearly depicts what they have missed while completing the case [Al-Dosari27]. Consequential feedback is common in branched VPs and instead of showing directly what is correct or wrong displays the consequences of wrong decisions [Round09]. Cumulative feedback shows students' progress across several solved cases and may encourage students' repeated use of VPs [Hirumi16]. Adaptive feedback is automatically adjusted to the answer given by the student [Berman16], [Sailer22]. This can be implemented by an artificial neural network based on former experiences of what kind of guidance worked previously well in a similar situation [Sailer22]. Another form could be the alteration of subsequently suggested VPs e.g., increasing or decreasing their difficulty level depending on performance of the learner [Berman16]. Radon et al. recommend carefully selecting the difficulty level of formative questions in VPs as too easy questions bore students and too difficult tend to frustrate. They recommend a level of 60% to 70% of the questions being answered correctly as a good balance [Radon11].

Caution is required when using automated feedback, even if for formative purposes, as students are sensitive to unfair judgment and such feedback may result in disappointment. This became apparent in the pilot evaluation of the iCoViP project when some students reported their disagreement with the way their concept maps integrated with VPs were graded. A potential risk is that when the feedback contains errors it will be difficult for the student to unlearn incorrect information.

Teachers should not rely on automatic feedback only as students also expect to discuss with them the cases [Edelbring11]. The iCoViP project partners recommend that automatically generated feedback should be checked and extended by teachers. This could be for instance in an integration scenario when the teacher observes live what the students are doing and helps them unblock some encountered difficulties. Follow-up seminars stimulate the students to post-case reflection, give opportunities to ask questions that could not be answered based on the computer presented materials and deepen the learning through a dialog with the teacher and peers [Posel15]. Formative assessment is also a valuable experience for the teachers as it informs them directly about the VP integration when there is still time for remedy and by that is part of ongoing curriculum evaluation and improvement [Wood19].

Recommendations:

- Take advantage of the different forms of formative assessment available in VPs that enable the students to compare their decisions in the diagnostic and treatment process with expert answers, checklists or to analyze exemplar responses.
- Artificial intelligence and natural language processing enable increasingly sophisticated ways of formative assessment that can be adaptive and include feedback to open-ended answers but remember that incorrect feedback is harmful and you should retain a healthy dose of skepticism before you trust innovation in automatic feedback.
- It is still very important that the computer generated feedback be reviewed and extended by human teachers. This improves the quality of feedback and allows the students to ask their teachers follow-up questions.

Subtheme: Learning analytics

Guiding questions:

1. What is the purpose of using learning analytics in VPs?
2. What data related to virtual patients is suitable for learning analytics and how to process and display it to the users?
3. What are the risks of using learning analytics in VPs?

The learning analytics process should be planned, otherwise we risk getting lost in the abundance of data [Lang11]. The rational approach is to use learning theories to pose a priori hypotheses that are then verified with the collected data [Cirigliano20]. It is important to decide what data to select for analysis. Examples of low-level, fine-grained activities in VPs that are frequently recorded and can be later used for learning analytics are time spent on tasks, mouse clicks on external links, zoom in of images, or answering questions [Kononowicz15], [Berman18], [Cirigliano20]. The recorded activities can already have some inherited meaning related to the trained competency. In the case of clinical reasoning training such activities include identifying relevant clinical findings, building and prioritizing differential diagnoses, making connections between clinical observations and hypotheses, writing summary statements, selecting diagnostics tests, committing to a final diagnosis, and declaring a confidence levels in decision-making [Doleck16], [Berman18], [Hege18]. Important is also the time sequence when student actions happened [Cendan12], [Doleck16]. The quality of those activities can be automatically assessed by checking against declared standards using sensitivity metrics (i.e., how much of the relevant information contained in each section the student was able to find), precision metrics (i.e., how many actions performed by the student were considered correct) [Furlan22], or by means of checking the degree of similarity to the expert solution using artificial intelligence methods - e.g. using clustering or natural language processing [Berman18], [Hege20]. Many VP systems allow exporting of recorded activity data in popular formats to enable learning analytics in external specialized statistical, machine learning or visualization tools.

When planning the use of learning analytics in VPs one should consider who is the target group of the outcomes [Knight17]. The audience could be directly the learners. In such cases results may illustrate to the students their progress in relation to their peers. This is intended to motivate them to become more engaged in their learning or to seek help from their teachers when struggling. For instance, Berman and Artino constructed a metric to judge student engagement while learning with VPs based on time spent on cards, accuracy of answering multiple-choice questions, number of added key finding and differential diagnoses, as well as machine-learning rating of summary statements [Berman18]. The metric was displayed for the learner in traffic light colors indicating low, medium, or high engagement. The conclusions from the pilot studies in the iCoViP project was to put learning analytics into context and not compare students who are very different - e.g. at different stages of their education, otherwise it might be frustrating or contribute to lower self-esteem of the students. Furlan et al. proposed to display learner performance in key aspects of clinical reasoning (such as history taking, physical examination or hypothesis generation) as radar graphs in relation to best, worst and average performance in the student cohort [Furlan22]. The comparisons of learner actions can be also relative to an expert performance. For instance, in a clinical reasoning tool developed by Hege et al., similarity of the learner’s clinical reasoning concept maps to the expert maps is displayed as percentage charts in a dashboard [Hege17].

The other possibility is to make teachers and faculty staff the target group of learning analytics. For them such data is useful for identification of struggling students for supporting actions, in judging the quality of education they provide, and in understanding the learning process. Cedan and Lok have developed a learning analytics tool that present on a time axis the individual actions taken during a patient scenario by the student and allows by that to visually inspect the process that led the student to reach the final diagnosis and by that identify outliers and seek patterns in a way that would have required time-consuming video analysis in the past [Cendan12]. Based on the collected data, computer algorithms can look for correlations of use of particular elements to learning performance indicators. A study by Cirigliano et al. showed that students rushing through VPs are likely to score low when answering related multiple choice questions [Cirigliano20]. Underutilization or poor correlation of particular VP elements with success indicators allow making judgments on the quality of material and plan refinements. For instance, after pilot evaluation in the iCoViP project a few VPs draw our attention by the unrealistic low diagnostic accuracy in students' answers. Based on that we corrected design errors that sneaked into the authoring process of VPs. Cirigliano et al. used learning analytics to question the utility of some external links and expert comments when not correlated with success on subsequent multiple-choice questions [Cirigliano20]. Finally, learning analytics is also a tool for virtual patient researchers. Hege et al. deepened the understanding of clinical reasoning learning with learning analytics methods applied to large collection of learner activities in VPs by showing differences between learners who diagnose the virtual patient until they find a correct answer in contrast to those who give up and request the answer is displayed by the system [Hege18].

Use of learning analytics is also connected with risks. Introduction of tools like engagement metrics is a form of extrinsic motivation [Berman18]. This is likely to influence the learning to improve the scores, but may not be connected with deeper learning, and in the worst case result in actions of superficial learning to game the system. Use of learning analytics may also compromise the feeling of safety in the learning environment. Students should be aware of which of their activities are tracked and retain the right to delete the recording of their activities while learning. Learning analytics may turn VPs more into an assessment tool, where students will be unlikely to show a candid approach of reflection and experimentation [Cirigliano17]. Labeling students based on learning analytics may do more harm than good when there is no firm evidence of validity of such a metric [Chan18]. This may backfire in discouragement and frustration when the system prematurely judges the student as not capable of reaching the desired performance level. Learning analytics is good in showing “what” is happening, but not necessarily “why” [Chan18]. Long time spent on activity may be caused by distraction of the student but also reflection, referencing to textbook or group work offline. It is recommended to triangulate the conclusions suggested by learning analytics with other sources of data that reflect students' intentions like verbal protocols, surveys or interviews [Cirigliano17].

In summary, the collection of large amounts of data in the process of learning with VPs and their analysis using statistical and machine learning methods has much potential in learner motivation, identification of struggling students, quality improvement of the VPs and better understanding of the learning process. However, the use of learning analytics should be cautious in order not to violate the safety of learning, induce superficial learning or make unwarranted judgments or predictions.

Recommendations:

- Learning analytics allows you to take advantage of large amounts of data recorded routinely in the process of student activities in VP systems for the benefits of learning, teaching or research.
- The recipients of learning analytics can be students who get an additional tool for motivation and feedback; teachers who can detect struggling students or flaws in the VP content and researchers to deepen the understanding of how students learn with VPs.
- Be careful not to impact by learning analytics the students’ feeling of safety while learning with VPs. Inform the students what activities are recorded and for what purpose the data is used and make your decisions based on learning analytics methods for which there is evidence of utility.

Subtheme: Summative assessment

Guiding question:

1. What should be verified before VPs are used as a summative assessment tool?
2. What are the opportunities and challenges in using VPs for summative assessment?
3. What are the preferences of students for the use of VPs in assessment?

There have been several attempts to use VPs in summative assessment (e.g. [Waldmann08], [Gunning12], [Setrakian20]). Because VPs depict the context of clinical decision making, they are believed to be particularly suitable to test application of knowledge and problem solving [Cook09], [Gesundheit09]. In this chapter we will briefly describe the opportunities, but also challenges with the use of VPs in summative assessment.

To use VPs for the purpose of summative assessment you should be able to present evidence for their quality as an assessment instrument. The two core criteria for that are reliability and validity [Schuwirth19]. In terms of reliability it should be remembered that clinical reasoning is content and context specific [Trowbridge15]. Making judgment on clinical reasoning based on performance in VPs requires many cases [Vleuten05]. Unfortunately, authoring VPs is expensive [Huang07]. The potential solution is to use for assessment purposes short VPs focusing on the key decision in the diagnostic and treatment process - so called electronic key-feature cases [Fischer05]. The strength of VPs in terms of assessment reliability when compared with such practice-oriented assessment forms as simulated patients and real patients is perfect reproducibility of examination conditions for all students. An identical case presentation with humans is impossible, while easily achieved with VPs [Waldmann08].

Validity evidence of a VPs-based assessment can be divided in content and construct validity [Schuwith19]. Regarding content validity the cases used in the examination should be selected to fit into an examination blueprint [Waldmann08]. This aims to ensure good coverage of topics of the case - e.g. in terms of leading symptom, disease group, setting and meeting the course learning objectives [Hege07]. Blueprinting is usually done by an expert panel after several rounds of discussion [Mayer22].

The other important aspect, construct validity, requires demonstrating correlation of the outcomes of this form of assessment with established examination methods (so called criterion measure). Unfortunately, this is rarely observed in studies. For instance, Waldmann et al. showed only weak correlation when comparing VPs with MCQ-based examinations [Waldmann08]. The likely explanation is that VPs examination is qualitatively different from regular exams [Botezatu10]. MCQ-based exams are more focused on theoretical knowledge corresponding to the low levels of Miller pyramid while VPs are believed to test higher level problem-solving abilities [Waldmann08]. The use of VPs is also beneficial in terms of reaching a better constructive alignment of the methods used in teaching and assessment. More emphasis is now being placed in medical education on the application of knowledge and this should be reflected by assessment methods [Gesundheit09]. Current curricula do not often assess explicitly clinical reasoning and there is no gold standard for that to reference [Kononowicz20]. This would explain the reason for the difficulty in showing correlations in former methods of assessment and not necessarily question the validity of VPs. This aspect still needs more research.

The idea of using VPs for summative assessment is attractive to some students [Botezatu10]. They see it as an authentic form of examination which is relevant to practice and wish to be tested that way. For instance, students argue that VPs are more realistic in assessment because of the ability to present abnormal findings which is not given with standardized patients [Gesundheit09]. Early-stage students are more in favor of using VPs in assessment than more advanced students [Gesundheit09].

There is also hope that using VPs for summative assessment will strengthen the clinical reasoning abilities by the end of the curriculum because students tend to focus on learning on what is being formally assessed [McEvoy12]. For a fair examination it is necessary that the students are familiar with the use of the system prior to the assessment [Gunning12], [Waldmann08]. It is also better not to push the students too much with time on such examinations [Gunning12]. Finally, the VP system used for summative assessment should be checked for security, failure tolerance and compliance with legal regulations [Haag10].

In summary, VPs have potential in summative assessment of clinical reasoning. However, judgment should not be made based on performance on a limited number of VPs and it should not be the only assessment form used. High acceptance of students for this assessment instrument is promising and encourages further development. At this stage none of the iCoViP partners uses the projects' VPs for summative assessment purposes and see them more as a tool for teaching than grading students.

Recommendations:

- VPs are a form of assessment regarded by students to be authentic and can extend the assessment offer of medical curricula by a tool to measure clinical reasoning skills.
- If you decide to use VPs for summative assessment you should be convinced about the validity and reliability of VPs used in the examination.
- It is important not to make assessment decisions based on a small sample of cases due to the problem of case specificity.

Glossary

Adaptive Learning

Adaptive learning or teaching is a method to deliver personalized learning experiences, based on students' preferences or previous performance, that address the unique needs of an individual, through just-in-time feedback, pathways, and resources (rather than providing a one-size-fits-all learning experience). Benefits of such adaptive learning environments are higher motivation and engagement of students, higher autonomy of learners, and a more inclusive way of teaching.

After Action Review

After Action Review (AAR) is a type of follow-up seminar useful for reflecting on students' experience during and after the completion of a project or a task (i.e., What did they learn? What did they like and why? What should be improved and how?). AAR is used to improve and practice for the next round of practical experience.

Blended Learning

Blended learning is an educational method, where online learning is combined with face-to-face teaching. There are several ways of mixing learning activities:

- Flipped classroom – which starts with an on-line asynchronous activity, followed by face-to-face meeting to discuss any open issues and perform hands-on-training.
- Online follow-up events organized after face-to-face small group sessions.
- Online activities can also be part of face-to-face teaching.

Important is that blended learning supports active learning by students and that online activities are not left isolated from the rest of educational activities. It is the role of the teacher to consider which learning objectives are best suited for online activities and for which it is better to meet with the students in person.

Branched VPs

Contrary to linear VPs, branched VPs do not follow only one linear story with one unique endpoint. Rather, it is a model of VPs where patient outcomes and thus the endpoint of the VP depend on the choices that the learner makes along the simulation. While working on the VP, the learner is given a set of choices at specific points during the story. The learner makes a decision and each choice leads the learner into a different possible scenario where choices have specific consequences for the patient. The final endpoint for the VP can be negative or positive depending on the aggregated decisions that the learner has made along the simulation.

Case-based learning

Case-based learning (CBL) also known as "case study teaching" or "case method learning", it is one of the teaching methods, a form of inquiry-based learning, which may be defined in a variety of ways depending on the context. Actually, as noted by Thistlethwaite et al. 2012, there is no international consensus over this definition. Nevertheless, overall, CBL involves students in a group interacting with each other in discussion on real-life examples to build knowledge and go through the case by analyzing given information (while the teacher plays only a role of facilitator and makes sure that the students keep on track). CBL is often contrasted to problem-based learning, and is positioned somewhere between structured and guided learning. The main principles of CBL are: making a connection between theory and practice, as well as developing clinical reasoning in health professions curricula.

Certificate

A certificate serves as a proof of accomplishment, for example when having completed a course and fulfilled certain requirements, such as reaching a specific score or completing a certain percentage of the activities. Often learning management systems, MOOC platforms, and virtual patient platforms provide certificates for their learners.

Clinical Placement

A clinical placement takes place under the general supervision of a qualified healthcare professional in a clinical context, usually including observation and/or interaction with patients. This learning might include taking a history, performing a physical examination, participating in clinical team meetings and patient case discussions/conferences, and the opportunity to observe and/or contribute to practical procedures, as deemed appropriate by the tutor responsible for supervising the student. It can also be a generic term for a non-academic training post filled by a doctor or other health professional in a clinical department or at the clinic. A student is placed in a clinical department to gain medical knowledge and competency and apply it on patients at the bedside.

Clinical Reasoning

Clinical reasoning is a complex process that uses cognition and discipline-specific knowledge to gather and analyze patient information, evaluate its significance, and weigh alternative actions. The way how clinical reasoning is conceptualized varies across health professions. It includes tasks such as data gathering and interpretation, synthesizing information, generating hypotheses and diagnoses, developing management plans that respects the patients' perspective, and avoiding cognitive errors. It is recognized as a key professional competency for practicing healthcare professionals.

Community of practice

A community of practice is a group of people who face the same tasks or challenges and form a community to learn from each other. Like networks, such communities are mostly self-organized, however, they differ in some aspects. Key characteristics of communities of practice are that the people involved not only feel committed and try to support each other but, they also aim at advancing the field of practice and sharing their knowledge and experience with a wider audience, especially those doing similar work.

Concept Maps

Concept maps are graphical tool for organizing knowledge. They consist of concepts, usually represented by boxes or circles that are connected to each another with lines. The lines represent relationships between the concepts, and the character of the connection is described by labels or sometimes indicated by color of the line. Concept maps are used in medical education to promote meaningful learning, to demonstrate basic science and clinical medicine linkages [Richards 2013], to assist teachers in providing feedback and to provide additional materials for learning [Daley 2016]. Additionally, concept maps are used in combination with virtual patients (VPs) to probe students' thought processes [Richards 2013] and to foster clinical reasoning [Hege 2017]. While solving VPs, students add to their concept maps important findings they observe in their patients, possible differential diagnoses, planned tests and indicated treatments. By adding connections between the concepts, they show how the elements are logically connected in the reasoning process. Students may compare their concept maps with maps created by experts to get feedback on their performance. All VPs in the iCoViP collection enable students to create their own concept maps and to receive feedback in form of author's maps that are stored in the system.

Constructive Alignment

Constructive alignment is a relation of appropriate arrangement of learning objectives, learning activities and assessment tasks to support effective education. Constructive alignment is related to outcome-based education – a shift in approach from focus on content to focus on what the student is able to do after learning. Constructive alignment starts with setting learning objectives. Then learning activities that fit the learning objectives need to be selected . Finally, it is important to plan assessments that correspond to what was planned the student should learn. For instance if the learning objective is to demonstrate clinical reasoning skills you cannot teach it in factsoverloaded lectures for large audiences and assess it with knowledge-oriented multiple-choice tests.

Corresponding teaching event

A corresponding teaching event is any teaching and learning activities in the curriculum (e.g. single session or closely connected online or offline learning activities) which go along with virtual patients (VPs). Those can be VPs used during problem-based learning or small-group discussions during follow-up seminars after working with VPs.

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Curriculum

Defined by Cambridge Dictionary as “subjects studied in a school, college etc., and what each subject includes.” It is also “Formal educational content, structure, and processes developed to enable students to perform at a competent level for a given stage of training” [Rencic 2015].
In the context of this guideline we mean by the curriculum all planned educational activities that taken together form the entire health professions training programme and are expected to be known and followed by students and their teachers. Curricula are disseminated to the stakeholders in various forms e.g. syllabi, course descriptions or curriculum maps.

Curriculum Mapping

Curriculum Mapping is a process of identifying a learning objectives or competency standard (e.g. a national competency framework) and showing how the content of the curriculum relates to that standard. Curriculum mapping answers the question of “where do we teach what?” and enables us to identify gaps, redundancies and elements that need to be strengthened in relation to what a standard indicates.

Deliberate Practice

Deliberate practice is defined as “practice that has a well-defined goal and tasks in which learners are motivated to improve, provided with feedback, and given opportunities for repetition and gradual refinements of their performance.” [Kotwal 2021]. Deliberate practice relies on the role of a teacher/coach to provide individualized feedback to revise attempts to reach the desired goal and level of performance. In case direct coaching is not possible, this role can be played by technology (e.g. by simulators or virtual patient simulations).

Distributed learning

Students and teachers are located in geographically distant locations and use the educational content asynchronously so that learning can occur independently from time and place. For instance, learners can solve VPs cases in distributed learning mode during their clinical placement period at different hospitals to have a comparable learning experience which is important to give all equal opportunities to pass an examination well regardless of the availability of real patients in clinical settings.

E-Portfolio

An e-portfolio is a digital version of a portfolio. Portfolios report on work done, feedback received, progress made, and plans for improving competence. The advantages of the electronic version of a portfolio are that they are easy to fill, manage and overview in distance by both the student and the tutor in charge.

Enquiry-based learning

Enquiry-based learning (EBL) is a broad umbrella term to describe approaches to learning that are driven by a process of enquiry. The tutor establishes the task and supports or facilitates the process, but the students pursue their own lines of enquiry, drawing on their existing knowledge and identifying the consequent learning needs. They seek evidence to support their ideas and take responsibility for analyzing and presenting this appropriately, either as part of a group or as an individual supported by others.

Entrustable Professional Activities (EPAs)

EPAsare tasks or responsibilities trusted to the trainees to perform on an unsupervised professional practice once they have fulfilled sufficient specific competence. These activities are independently executable, observable and measurable in their process and outcome. EPAs are context-dependent, which means that those should be taught and applied in common medical situations and conditions for patients of any age.

Exam relevance

Knowledge and skills might possess an “exam relevance” feature as it refers to a material that may appear on the exam. Exam relevance is a common reason given for students to learn the material. Students show higher preference to learn the material when they know that it will be in the exam e.g. examination from a licensing body such as the National Board of Medical Examiners in the United States or the Medical Council of Canada.

Exam-relevant integration strategy

Educators provide VPs as an add-on activity to other curricular components and tell the students that part of the VP content will be exam relevant (e.g., as an incentive for the students to complete the VPs in a voluntary setting). For instance, about 10% of the questions in the final internal medicine exam are related to selected VPs or one station in the OSCE exam at the end of the term is implemented as an online key feature exam on selected VPs presented during preparation.

Examination Blueprint

An examination or assessment blueprint is a plan of the content of an assessment that defines emphasis (in percentage) allocated to covered topics (e.g. 10% cardiovascular disease, 5% psychiatry) and other important characteristics like tested competencies, time, and item formats.

The level of details of a blueprint varies depending on the stake of the assessment. A blueprint provides evidence for validity of the examination.

Expert comment

In a virtual patient system an expert comment is an additional clarification that does not fit in the natural narration of the case. Expert comments could for instance refer to clinical guidelines or explain local practice, characteristic for a particular country, or type of setting. Another solution is to embed additional clarification or explanation of what or why something is happening into the dialogs of characters in the patient story – e.g. by introducing the person of a clinical supervisor or experienced nurse who provided the missing information. This allows telling a story that is uninterrupted by didactical elements to retain the feeling of authenticity. This realistic presentation is what virtual patients are valued for.

Flipped classroom

Flipped classroom is a specific form of blended learning, where, in contrast to the traditional model, students are required to prepare prior to the class (with reading, self-study or other online asynchronous activities) and then bring their knowledge, questions and ideas for a group discussion, lecture or, hands-on training session. This method allows students to develop critical thinking and apply knowledge into practice. The flipped classroom model promotes the integration of independent learning and the use of technology outside the classroom and more efficient student–teacher interactions in the classroom.

Formative assessment

Formative assessment is a form of assessment designed specifically to provide feedback. The purpose is to stimulate or modify learning showing the gaps in the progress of education. It is different from summative assessment that has the goal to verify achievement of intended learning goals to allow passage to more advanced stages of education or set ranks in a group by the end of a study unit. Formative assessment should be frequent, non-judgmental and promote self-directed learning. It is especially effective when provided in a safe and supportive environment. The ultimate goal of formative assessment is to foster deep learning.

Graphical fidelity

Mechanics and dynamics used in a media that will affect the user experience. Different attributes, such as form, motion, material, and light will render different levels of graphical fidelity from simplified to stylized or naturalistic.

Human patient simulator

Human patient simulators (HPS) are life-size human-like mechanical and computer controlled manikins that replicate elements of human physiology such as respiration, heart beat and pulse. They can display symptoms and disease processes as they are present in a real patient, can accurately respond to procedures such as mechanical ventilation, CPR, intravenous medication, or catheterization. HPS are used in health care education for role playing, skills building, and hands-on, active education.

Integrated curriculum

An integrated curriculum implies learning that is synthesized across traditional subject areas and learning experiences that are designed to be mutually reinforcing.
It is an educational strategy that involves organization of learning material around topics related to the practice of the profession rather than scientific discipline, for example around presenting clinical problems, body systems, clinical situations or age. It requires coordinated presentation of knowledge, skills and beliefs coming from different disciplines and a more central management of the curriculum. In an integrated curriculum diabetes mellitus may be presented in a module in parallel from the perspective of insulin-related biochemistry, physiology, pharmacology with consideration of wider public health disparities around prediabetes [Matinho 2022]. Integrated curricula are perceived by students as more relevant and helpful to acclimatize to professional expectation. The teachers support students in making links between subject areas and apply cross-disciplinary knowledge to clinical practice. Curricula often differ in the extent to which the integration was accomplished on the continuum from complete disciplinary isolation to a complete transdisciplinary curriculum achieved sometimes by the end of the study programme [Harden 2000].

Integration into a curriculum

Integration means “the process of combining with other things in a single larger unit or system” [MacMillian Dictionary].
Virtual patient integration is a state in which a VP or set of VPs is part of learners’ normal training schedule, embedded in curriculum (curricular integration), which means that the VPs are listed in the syllabus as a mandatory or recommended learning activity, time is reserved for VP activities and what the students learn with VPs is relevant for how their performance is evaluated. It can be a part of the educational design process, where virtual patients can be effectively combined with other learning activities in the curriculum.
Integrated learning with virtual patients means to use virtual patients in order to stimulate the learner to combine knowledge and skills from different disciplines in one activity.
Finally, technical integration of virtual patients means all the IT solutions which enable automated control or data transfer between different software tools to facilitate a seamless learning experience for the students (e.g. automated authorization, combination of virtual patient activities with other educational electronic tools in learning management systems, as well as data transfer for learning analytics or performance documentation purposes).

Internationalization

Internationalization is a process of purposefully integrating international, intercultural, or global dimensions into medical education in order to enhance its quality and prepare graduates for professional practice in a globalized world.

Key-feature cases

A key-feature is a critical step in problem solving. Those steps should be likely to cause problems to students and be important in making a diagnosis or management decision. Key-feature problems start with a clinical vignette and contain usually 2-3 questions regarding the vignette. The questions require write-in of an answer or selection of an option from a long list. Fischer et al. transfer the idea to an electronic version available as short cases (i.e. key-feature cases) in the VP system CASUS. Key-feature cases replace longer cases (i.e. Patient Management Problems) in assessment of clinical reasoning because they allow testing more clinical decisions in a shorter time, are less case-specific and by that more reliable as an assessment form.

Key features

Key feature questions are the decisions pivotal to the successful outcome of a patient case [Farmer 2005]. These are challenging aspects in the diagnosis and management of a clinical problem where the students are most likely to make errors. A key-feature question starts with a short patient vignette (age, gender, setting, reason for consultation etc.) which is followed by 2-3 multiple choice questions based on the same vignette and focused on testing key features. The first question is usually about the diagnosis and the second on the treatment. In order not to cue the right answer the candidates are requested to select answers from a booklet of many possible answers or from a long-menu in case of computer-based key-feature questions.

Knowledge Encapsulation

Knowledge encapsulation is the process of merging several facts about a concept under one term. According to the Cognitive Load Theory, the number of chunks of information we are able to simultaneously process in our working memory is very limited. To overcome this limitation, we may subconsciously encapsulate several of these information chunks into expressive concepts (e.g., “sepsis”). In case it is needed, experts are able, with some additional mental effort, to deliberately “unpack” this knowledge to rationalize their decisions. This explains the effectiveness of thinking by medical experts and also justifies the need to keep basic science knowledge in the curriculum, even if it might seem that medical experts do not use it in their clinical practice.

Learner-centered Education

A learner-centered approach emphasizes learning as the result of a student’s active engagement in learning activities. This means activities where the learners are responsible participants in the learning task. It places the learner’s experiences, development of knowledge, and meaning in the center of the learning process. The teacher’s role is supporting and facilitating the learning process and provide feedback.

Learning analytics

Learning analytics (LA) means the collection and aggregation of large sets of student data and its analysis and reporting / visualization. The aims of LA can be to:

1. understand the learners and help them to master the learning, e.g., by providing tailored feedback
2. evaluate and improve learning activities
3. detect students at risk of failing a course or program
4. develop predictions about students’ performances.

Using statistical and data mining methods makes it possible to detect meaningful patterns to improve learning. This is given in the case of electronic learning tools that have been used for a long time, in large scale events like Massive Open Online Courses or when sharing learning resources by many institutions. However, ethical and data-protection aspects are important to be considered. Virtual patient environments, similar to learning management systems, typically record and store learners' interactions with the system and this data can be used for providing system-generated or tutor-guided feedback.

Learning objectives

Learning objectives, also known as intended learning outcomes, are statements that define the knowledge, skills and attitudes students should acquire or develop by the end of a particular assignment, class, course, or program. Learning objectives help students understand why that knowledge and those skills will be useful to them. According to Gronlund et al. "they help to articulate what students should be able to do as a result of the instruction and consequently aid in designing more effective instruction planning, activities, and assessments" [Gronlund 2000]. Well-designed learning objectives define educational goals to help learners assess their proficiency and achievements of a desired outcome [Hui 2021].

Mandatory cases strategy

In order to pass a course or other learning activity successfully, students are obliged to complete a certain number of virtual patients (VPs). The minimum requirements on the quality of completion of the VP can be set in advance, e.g., "50% correct answers, session duration of at least 20 minutes and 100% completed screen cards."

Miller pyramid

The Miller pyramid describes the development of clinical competence on four, hierarchical processes:

- The lowest level is **knowledge** (basis of the pyramid), assessed mainly by written exams (e.g., MCQs)
- The second level is the **application of knowledge**, assessed for example with essays or oral assessments.
- The third level is the **clinical skills competency**, assessed for example in OSCEs.
- The top of the pyramid is **clinical performance**, assessed with workplace-based exams

MOOCs

Massive Open Online Courses (MOOCs) are online courses that contain open and freely available educational resources in the form of digitized materials for educators, students, and self-learners to use and reuse in teaching, learning, and research. Their "massive" characteristic refers to the fact that these courses are offered asynchronously to a large number of individuals (typically more than 500, but possibly up to 100.000 participants). Besides benefitting from digitized course materials, MOOCs allow users to interact with other learners, and share the learned materials with others through the MOOC platform. MOOCs are usually designed and offered by universities in partnership with online platforms such as Coursera, edX, or FutureLearn.

Natural language processing

Natural language processing is a field of computer science, artificial intelligence, and linguistics developed to make computers understand and manipulate written or spoken human languages (“natural languages”). In the context of virtual patients, natural language processing means that the learners can communicate with virtual patients by freely asking questions in written or oral form as in a conversation with a real patient, rather than by selecting options from lists or menus of pre-defined options.

Near-peer teaching

Near-peer teaching (NPT) describes communication or activity between people or organizations that are very similar or nearly equal. It is a highly valuable learning strategy for the education of medical undergraduates. In near peer teaching a more experienced student acts as the instructor and passes on their knowledge or provides feedback to other students. (Cambridge Dictionary)

Not-invented-here syndrome

Ideas, products, or existing knowledge are disregarded by individuals (or institutions) only because they originate from someone (or somewhere) else. The phenomenon harbors the risk of stifling innovations or wasting time, money, and effort (e.g., for re-inventing things that already exist).

Problem-based learning

Problem-based learning (PBL) is a student-centered teaching method in which complex real-world problems are used as the vehicle to promote student learning of concepts and principles, as opposed to direct presentation of facts and concepts. In addition to course content, PBL aligns with rules of contextual, constructive, collaborative and self-directed learning. It can also promote the development of critical thinking, problem-solving abilities, and communication skills. PBL allows students sharing their existing knowledge on a problem and at the same time learning new things from each other and identifying their learning gaps that they can still work on. This type of teaching method also provides opportunities to learn how to find and evaluate the quality of research material and gain some presentation skills. As in CBL, teachers in PBL activities play the role of the facilitators, guiding students through the problem to be solved.

Productive Struggle

Productive Struggle is a term derived from mathematical sciences and means a “process of effortful learning that develops grit and creative problem solving”. To better understand it, imagine students who have to a problem to solve. They do not know the answer right away, but educators do not want them to stop at that point and finish their attempts. It is about encouraging students to use their prior knowledge, to create new concepts based on given data, and to try different approaches to find solutions. It is also about assigning students more and more challenging tasks, so they can “stretch their brains.”

Scaffolding

Scaffolding is an instructional method which helps students to become more and more independent learners. When new to a topic or task, learners will need more support, e.g., in the form of prompts, examples, or hints, but over the time it becomes less necessary. The teacher initially may share new information or demonstrate how to solve a problem and then gradually steps back and lets students practice on their own. It also can involve group practice.

Screen cards

Screen cards are units of information presented at once to the user in unfolding stories of virtual patients. The learner gets first a portion of information about the patient situation, is requested to reflect on the presented situation and after that is allowed to move to the next stage where more information is presented, and so forth. They would correspond to slides in PowerPoint presentations or printouts given to students in a problem-based learning session. Screen cards can also contain multimedia resources, interactive exercises (e.g. multiple choice questions), and expert comments.

Self-directed learning

Self-directed learning (SDL) is a process that has been described as early as 1975, by an American adult educator Malcolm Knowles as a process in which educators become facilitators, and learners take the initiative to recognize knowledge deficits, determine learning goals, identify credible learning resources, implement plans, and evaluate those plans for success [Knowles 1975]. A more recent definition describes SDL as "education that derives from the self-chosen activities and life experiences of the learner." (Source)

Semantic qualifiers

Semantic qualifiers are the descriptors (usually paired) that are used by clinicians to compare or contrast clinical phenomena. Clinicians transform the information provided by the patient into descriptive terms in order to understand, process, and facilitate evoking information that is relevant for clinical reasoning. For example, 'I had this problem before' becomes 'recurrent' and 'only one joint is swollen' becomes 'monoarticular'. Semantic qualifiers serve as a bridge between clinical and basic science knowledge.

Semiology

Semiology (in a medical context) means study of signs. Sometimes also called semiotics, but it is important to note that those two words are not synonyms. Semiotics and semiology share a similar etymology and meaning. In medicine, signs are objective manifestations of disease, as opposed to the subjective nature of symptoms. Semiology comprises the study of symptoms, somatic signs and laboratory signs, history taking and physical examination (in English-speaking countries is known as Bedside diagnostic examination or Physical diagnosis).

Simulated Patients

A simulated patient (SP) is a human actor who plays the role of an actual patient with a specific condition in a realistic way, used in simulated scenarios for teaching communication and physical examination skills. Simulated patients can be additionally trained to give feedback and assess students. They are usually lay people but sometimes also volunteer patients. If the emphasis of training a simulated patient is to portray the disease consistently which does not vary from student to student (e.g. feature used in OSCE exams), they are also called standardized patients.

Spaced activation

Spacing means to work on a task in multiple sessions rather than in one session. Virtual patients are spaced activated if they are not released to the students at the same time (bolus learning) but rather distributed over time (e.g., a certain number each week) or when other conditions are fulfilled (e.g., when previous virtual patients have been completed or a certain score threshold is reached). Spaced activation is observed to result in more balanced learning activities without cumulation of the workload in a short period. This can lead to longer lasting learning effects.

Standardized Patients

See Simulated Patients

Stock photography

Stock photography refers to the process of generating photographs that were originally not taken to suit a specific customer's demands, but to become part of a collection or database and available to be sold or rented to the final customer. In stock photography, the image already exists at the time that the customer requests it. In stock photography, the photographer retains physical or legal property of the photograph, i.e. the photographer remains the copyright holder. According to Frosh (2008), stock photography also refers to the industry that creates, promotes, and distributes these images for later use.

Summary statement

Summary statements are short texts of two or three sentences that succinctly represent the patient's health problems in the context of a VP simulation. This helps learners elaborate and show the process of mental abstraction done by transforming relevant patient-specific details using semantic qualifiers.

Summative assessment

The goal of summative assessment is to evaluate student learning at the end of a defined instructional period (e.g. unit, course, project, semester, academic year) by comparing it against some standard or benchmark. It is a decision-making process regarding the competence of the assessed learner. There are many assessment instruments available in medical education (e.g. written examination as MCQ-test; practice-oriented OSCE examination, workplace-based as Mini-CEX) with different characteristics. The quality of assessment instruments is demonstrated by their reliability and validity. No single tool can cover all medical competences nor have psychometric properties superior to all other forms of examination. For that reason the recommendation is to select an assessment tool depending on the intended aspect of medical competence.

Usability guidelines

ISO standards (e.g. ISO 9241-11) define usability as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use". In our context it is the ease with which learners can operate the user interface of a VP system. Research in usability of computer interfaces resulted in several rules about what to do or what to avoid in order to design software with good usability. Among the most popular are the usability heuristics defined by Nielsen Group and the W3C Web Accessibility Initiative.

Virtual Patient

A virtual patient (VP) is “a type of computer software that simulates real-life clinical scenarios, in which the learner emulates the role of health care provider to obtain the history, conduct examination, and make diagnoses and management decisions.” [AAMC 2007]
This guideline focuses on VPs that aim to foster clinical reasoning or directly are related to those skills. Those scenarios unfold in time, and are available on desktop computers or mobile devices, accessible with a web browser or installed application. Typical VPs consist of text description of the cases narration extended by multimedia material (e.g., audio clips, x-rays, MRI scans etc.) and interactive elements that help to structure the clinical reasoning process. We do not include in this guideline VP in immersive virtual reality environments (e.g. require a mixed/virtual reality headset), haptic devices (interfaces for controlling the simulation using the sense of touch, force feedback, gestures), any form of mannequins and part-task trainers or simulation in which the role of the patient is played by human.

Virtual patient panel

A VP panel is a collection of deliberately selected virtual patients, instead of a single virtual patient, addressing specific topics.

Voluntary integration strategy

Virtual patients (VPs) are provided as an add-on activity to other curricular components (e.g. addition to a lecture). Students who complete VPs do not get any additional credit points but can be rewarded otherwise, for example in the form of a certificate. In a voluntary setting, educators can decide to make part of the VP content exam relevant as an incentive for the students to complete the VPs.

VP Design Features

Variables and process steps that relate to the content of the VP itself and its authoring – e.g. narration style, types of questions, multimedia files, references to medical evidence/guidelines, interactive elements (long menus, navigation between the content, concept maps) without explicit link to how the VP is used in a particular curriculum. When referring to VP design features we treat VPs as self-contained learning resources (like books) that can be used in any educational context without considering its adaptation for the needs of the environment in which it is going to be used.

References

- Al-Dosari, S. H., Al-Drees, A., Al-Qahtani, F. S., Alajji, N. A., & Al-Qahtani, A. A. (2017). Virtual Patient as A Multimedia Learning Tool to Help Students Learn Clinical Reasoning Skills in Medicine. International Journal of Pharmaceutical Research & Allied Sciences, 6(4).
- Altmiller G, Alexy E, Dzubaty D, Jakubowski T, Kartoz CR. Systematic Curriculum Mapping of Virtual Patient Assignments to End-of-Program Outcomes. Nurse Educ. 2022 Mar-Apr 01;47(2):69-74.
- Baumann-Birkbeck L, Florentina F, Karatas O, Sun J, Tang T, Thaung V, McFarland A, Bernaitis N, Khan SA, Grant G, Anoopkumar-Dukie S. Appraising the role of the virtual patient for therapeutics health education. Curr Pharm Teach Learn. 2017 Sep;9(5):934-944.
- Benedict N, Schonder K, McGee J. Promotion of self-directed learning using virtual patient cases. Am J Pharm Educ. 2013 Sep 12;77(7):151.
- Berman N, Fall LH, Smith S, Levine DA, Maloney CG, Potts M, Siegel B, Foster-Johnson L. Integration strategies for using virtual patients in clinical clerkships. Acad Med. 2009 Jul;84(7):942-9.
- Berman NB, Fall LH, Chessman AW, Dell MR, Lang VJ, Leong SL, Nixon LJ, Smith S. A collaborative model for developing and maintaining virtual patients for medical education. Med Teach. 2011;33(4):319-24.
- Berman NB, Durning SJ, Fischer MR, Huwendiek S, Triola MM. The Role for Virtual Patients in the Future of Medical Education. Acad Med. 2016 Sep;91(9):1217-22.
- Berman NB, Artino AR Jr. Development and initial validation of an online engagement metric using virtual patients. BMC Med Educ. 2018 Sep 17;18(1):213.
- Boeker M, Klar R. E-Learning in der ärztlichen Aus- und Weiterbildung. Methoden, Ergebnisse, Evaluation [E-learning in the education and training of physicians. Methods, results, evaluation]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2006 May;49(5):405-11.
- Botezatu M, Hult H, Kassaye Tessma M, Fors UG. As time goes by: Stakeholder opinions on the implementation and use of a virtual patient simulation system. Med Teach. 2010;32(11):e509-16.
- Botezatu M, Hult H, Fors UG. Virtual patient simulation: what do students make of it? A focus group study. BMC Med Educ. 2010 Dec 4;10:91.
- Bowden S, Kirubarajan A, Balbaa A, Berditchevskaia I, Freeman S, Klostermann N, Naguib M, Kurabi B, Law M, Lazor J. Evaluating and implementing an opportunity for diversity and inclusion in case-based learning. Can Med Educ J. 2021 Sep 14;12(4):146-148.
- Bowen JL. Educational strategies to promote clinical diagnostic reasoning. N Engl J Med. 2006 Nov 23;355(21):2217-25.
- Braun LT, Borrmann KF, Lottspeich C, Heinrich DA, Kiesewetter J, Fischer MR, Schmidmaier R. Scaffolding clinical reasoning of medical students with virtual patients:

effects on diagnostic accuracy, efficiency, and errors. Diagnosis (Berl). 2019 Jun 26;6(2):137-149.

- Casanova R, Miller V, Cheon J, Gilmore L, Barron R, Cannaday R, Case G, Digre K, Jensen J, McGregor AJ, Pippitt K, Davidge-Pitts C, Pomeroy B, Webster D, Jenkins M. Field Test Results of Sex- and Gender-Specific Health Multimedia Case-Based Learning Modules. J Womens Health (Larchmt). 2019 Dec;28(12):1755-1761
- Cederberg RA, Bentley DA, Halpin R, Valenza JA. Use of virtual patients in dental education: a survey of U.S. and Canadian dental schools. J Dent Educ. 2012 Oct;76(10):1358-64.
- Cendan J, Lok B. The use of virtual patients in medical school curricula. Adv Physiol Educ. 2012 Mar;36(1):48-53.
- irigliano MM, Guthrie C, Pusic MV, Cianciolo AT, Lim-Dunham JE, Spickard A 3rd, Terry V. "Yes, and …" Exploring the Future of Learning Analytics in Medical Education. Teach Learn Med. 2017 Oct-Dec;29(4):368-372
- Chan T, Sebok-Syer S, Thoma B, Wise A, Sherbino J, Pusic M. Learning Analytics in Medical Education Assessment: The Past, the Present, and the Future. AEM Educ Train. 2018 Mar 22;2(2):178-187.
- Cirigliano MM, Guthrie CD, Pusic MV. Click-level Learning Analytics in an Online Medical Education Learning Platform. Teach Learn Med. 2020 Aug-Sep;32(4):410-421.
- Conradi E, Kavia S, Burden D, Rice A, Woodham L, Beaumont C, Savin-Baden M, Poulton T. Virtual patients in a virtual world: Training paramedic students for practice. Med Teach. 2009 Aug;31(8):713-20.
- Cook DA, Triola MM. Virtual patients: a critical literature review and proposed next steps. Med Educ. 2009 Apr;43(4):303-11.
- Dafli E, Fountoukidis I, Hatzisevastou-Loukidou C, D Bamidis P. Curricular integration of virtual patients: a unifying perspective of medical teachers and students. BMC Med Educ. 2019 Nov 9;19(1):416.
- Dahri K, MacNeil K, Chan F, Lamoureux E, Bakker M, Seto K, Yeung J. Curriculum integration of virtual patients. Curr Pharm Teach Learn. 2019 Dec;11(12):1309-1315.
- Daley, B. J., Durning, S. J., & Torre, D. M. (2016). Using concept maps to create meaningful learning in medical education. MedEdPublish, *5*(19), 19.
- Dankbaar ME, Alsma J, Jansen EE, van Merrienboer JJ, van Saase JL, Schuit SC. An experimental study on the effects of a simulation game on students' clinical cognitive skills and motivation. Adv Health Sci Educ Theory Pract. 2016 Aug;21(3):505-21.
- Dewhurst D, Borgstein E, Grant ME, Begg M. Online virtual patients - A driver for change in medical and healthcare professional education in developing countries? Med Teach. 2009 Aug;31(8):721-4.
- Djukic M, Fulmer T, Adams JG, Lee S, Triola MM. NYU3T: teaching, technology, teamwork: a model for interprofessional education scalability and sustainability. Nurs Clin North Am. 2012 Sep;47(3):333-46.
- Doleck T, Jarrell A, Poitras EG, Chaouachi M, Lajoie SP. Examining diagnosis paths: A process mining approach. Proceedings - 2016 2nd International Conference on Computational Intelligence and Communication Technology, CICT 2016 IEEE; 2016: 663–667.

- Doloca AD, Tanculescu OA, Trandafir L, Ciongradi I, Stoleriu S, Mocanu R, Ifteni G. Dental materials and their selection-virtual patient (VP) software from a student perspective. Materiale plastice. 2016 Sep 1;53(3):370-4.
- Edelbring S, Dastmalchi M, Hult H, Lundberg IE, Dahlgren LO. Experiencing virtual patients in clinical learning: a phenomenological study. Adv Health Sci Educ Theory Pract. 2011 Aug;16(3):331-45.
- Edelbring S, Broström O, Henriksson P, Vassiliou D, Spaak J, Dahlgren LO, Fors U, Zary N. Integrating virtual patients into courses: follow-up seminars and perceived benefit. Med Educ. 2012 Apr;46(4):417-25.
- Edelbring S, Parodis I, Lundberg IE. Increasing Reasoning Awareness: Video Analysis of Students' Two-Party Virtual Patient Interactions. JMIR Med Educ. 2018 Feb 27;4(1):e4.
- Edelbring S, Broberger E, Sandelius S, Norberg J, Wiegleb Edström D. Flexible interprofessional student encounters based on virtual patients: a contribution to an interprofessional strategy. J Interprof Care. 2022 Mar-Apr;36(2):310-317.
- Ellaway RH, Davies D. Design for learning: deconstructing virtual patient activities. Med Teach. 2011;33(4):303-10.
- Ellaway R, Topps D, Lee S, Armson H. Virtual patient activity patterns for clinical learning. Clin Teach. 2015 Aug;12(4):267-71.
- Elstein, A.S., Shulman L.S., and Sprafka S.A.. Medical problem solving an analysis of clinical reasoning. (1978).
- Fall LH, Berman NB, Smith S, White CB, Woodhead JC, Olson AL. Multi-institutional development and utilization of a computer-assisted learning program for the pediatrics clerkship: the CLIPP Project. Acad Med. 2005 Sep;80(9):847-55.
- Fischer MR, Kopp V, Holzer M, Ruderich F, Jünger J. A modified electronic key feature examination for undergraduate medical students: validation threats and opportunities. Med Teach. 2005 Aug;27(5):450-5.
- Fischer MR, Hege I, Hörnlein A, Puppe F, Tönshoff B, Huwendiek S. Virtuelle Patienten in der medizinischen Ausbildung: Vergleich verschiedener Strategien zur curricularen Integration [Virtual patients in medical education: a comparison of various strategies for curricular integration]. Z Evid Fortbild Qual Gesundhwes. 2008;102(10):648-53.
- Fors UG, Muntean V, Botezatu M, Zary N. Cross-cultural use and development of virtual patients. Med Teach. 2009 Aug;31(8):732-8.
- Furlan R, Gatti M, Mene R, Shiffer D, Marchiori C, Giaj Levra A, Saturnino V, Brunetta E, Dipaola F. Learning Analytics Applied to Clinical Diagnostic Reasoning Using a Natural Language Processing-Based Virtual Patient Simulator: Case Study. JMIR Med Educ. 2022 Mar 3;8(1):e24372.
- Geha R, Trowbridge RL, Dhaliwal G, Olson APJ. Teaching about diagnostic errors through virtual patient cases: a pilot exploration. Diagnosis (Berl). 2018 Nov 27;5(4):223-227.
- Gesundheit N, Brutlag P, Youngblood P, Gunning WT, Zary N, Fors U. The use of virtual patients to assess the clinical skills and reasoning of medical students: initial insights on student acceptance. Med Teach. 2009 Aug;31(8):739-42.
- Gillham D, Tucker K, Parker S, Wright V, Kargillis C. CaseWorld™: Interactive, media rich, multidisciplinary case based learning. Nurse Educ Pract. 2015 Nov;15(6):567-71.

- Gunning WT, Fors UG. Virtual patients for assessment of medical student ability to integrate clinical and laboratory data to develop differential diagnoses: comparison of results of exams with/without time constraints. Med Teach. 2012;34(4):e222-8.
- Guetterman TC, Sakakibara R, Baireddy S, Kron FW, Scerbo MW, Cleary JF, Fetters MD. Medical Students' Experiences and Outcomes Using a Virtual Human Simulation to Improve Communication Skills: Mixed Methods Study. J Med Internet Res. 2019 Nov 27;21(11):e15459.
- Haag, M., & Huwendiek, S. The virtual patient for education and training: A critical review of the literature. it-Information Technology, 2010, *52*(5), 281-287.
- Haerling KA. Cost-Utility Analysis of Virtual and Mannequin-Based Simulation. Simul Healthc. 2018 Feb;13(1):33-40.
- Hege I, Ropp V, Adler M, Radon K, Mäsch G, Lyon H, Fischer MR. Experiences with different integration strategies of case-based e-learning. Med Teach. 2007 Oct;29(8):791-7.
- Hege I, Kononowicz AA, Tolks D, Edelbring S, Kuehlmeyer K. A qualitative analysis of virtual patient descriptions in healthcare education based on a systematic literature review. BMC Med Educ. 2016 May 13;16:146.
- Hege I, Kononowicz AA, Adler M. A Clinical Reasoning Tool for Virtual Patients: Design-Based Research Study. JMIR Med Educ. 2017 Nov 2;3(2):e21.
- Hege I, Kononowicz AA, Kiesewetter J, Foster-Johnson L. Uncovering the relation between clinical reasoning and diagnostic accuracy - An analysis of learner's clinical reasoning processes in virtual patients. PLoS One. 2018 Oct 4;13(10):e0204900.
- Hege I, Kiesewetter I, Adler M. Automatic analysis of summary statements in virtual patients - a pilot study evaluating a machine learning approach. BMC Med Educ. 2020 Oct 16;20(1):366.
- Hirumi, A, Johnson, T, Reyes, R. J., Lok, B, Johnsen, K, Rivera-Gutierrez, D. J, ... & Cendan, J. Advancing virtual patient simulations through design research and interPLAY: part II—integration and field test. Educational technology research and development, 64(6), 2016, 1301-1335.
- Holmboe, E.S. and Harden, R.M., 2021. Outcome-based education. Dent, J. , Harden, RM, Hunt, D.(Eds.). A Practical Guide for Medical Teachers, 6th ed., Edinburgh: Elsevier, pp.129-37.
- Hooper C. Ethics virtual patients: a new pedagogical tool for educators? J Med Ethics. 2015 Jul;41(7):549-52.
- Huang G, Reynolds R, Candler C. Virtual patient simulation at US and Canadian medical schools. Acad Med. 2007 May;82(5):446-51.
- Huwendiek S, Muntau AC, Maier EM, Tönshoff B, Sostmann K. E-Learning in der medizinischen Ausbildung. Monatsschrift Kinderheilkunde. 2008 May;156(5):458-63.
- Huwendiek S, Duncker C, Reichert F, De Leng BA, Dolmans D, van der Vleuten CP, Haag M, Hoffmann GF, Tönshoff B. Learner preferences regarding integrating, sequencing and aligning virtual patients with other activities in the undergraduate medical curriculum: A focus group study. Med Teach. 2013 Nov;35(11):920-9.

- Huwendiek S, De Leng BA, Kononowicz AA, Kunzmann R, Muijtjens AMM, Van Der Vleuten CPM, Hoffmann GF, Tönshoff B, Dolmans DHJM. Exploring the validity and reliability of a questionnaire for evaluating virtual patient design with a special emphasis on fostering clinical reasoning. Med Teach. 2015 Aug;37(8):775-782.
- Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Med Teach. 2005 Jan;27(1):10-28.
- Johnson TR, Lyons R, Chuah JH, Kopper R, Lok BC, Cendan JC. Optimal learning in a virtual patient simulation of cranial nerve palsies: the interaction between social learning context and student aptitude. Med Teach. 2013;35(1):e876-84.
- Johnson TR, Lyons R, Kopper R, Johnsen KJ, Lok BC, Cendan JC. Virtual patient simulations and optimal social learning context: a replication of an aptitude-treatment interaction effect. Med Teach. 2014 Jun;36(6):486-94.
- Kim S, Willett LR, Pan WJ, Afran J, Walker JA, Shea JA. Impact of Required Versus Self-Directed Use of Virtual Patient Cases on Clerkship Performance: A Mixed-Methods Study. Acad Med. 2018 May;93(5):742-749.
- Kleinheksel, A. J., & Ritzhaupt, A. D. (2017). Measuring the adoption and integration of virtual patient simulations in nursing education: An exploratory factor analysis. Computers & Education, 108, 11-29.
- Knight, S. Shum, SB. Theory and learning analytics. Handbook of learning analytics, 2017, 17-22.
- Kolb S, Reichert J, Hege I, Praml G, Bellido MC, Martinez-Jaretta B, Fischer M, Nowak D, Radon K; NetWoRM group. European dissemination of a web- and case-based learning system for occupational medicine: NetWoRM Europe. Int Arch Occup Environ Health. 2007 May;80(6):553-7.
- Kolb S, Wengenroth L, Hege I, Praml G, Nowak D, Cantineau J, Cantineau A, Gonzalez M, Monso E, Pauncu EA, Dev Vellore A, Godnic-Cvar J, Radon K; NetWoRM Group. Case based e-learning in occupational medicine--a European approach. J Occup Environ Med. 2009 Jun;51(6):647-53.
- Kononowicz AA, Krawczyk P, Cebula G, Dembkowska M, Drab E, Frączek B, Stachoń AJ, Andres J. Effects of introducing a voluntary virtual patient module to a basic life support with an automated external defibrillator course: a randomised trial. BMC Med Educ. 2012 Jun 18;12:41.
- Kononowicz AA, Zary N, Edelbring S, Corral J, Hege I. Virtual patients--what are we talking about? A framework to classify the meanings of the term in healthcare education. BMC Med Educ. 2015 Feb 1;15:11.
- Kononowicz AA, Berman AH, Stathakarou N, McGrath C, Bartyński T, Nowakowski P, Malawski M, Zary N. Virtual Patients in a Behavioral Medicine Massive Open Online Course (MOOC): A Case-Based Analysis of Technical Capacity and User Navigation Pathways. JMIR Med Educ. 2015 Sep 10;1(2):e8.
- Kononowicz AA, Woodham L, Kavia S, The different dimensions of widening access to virtual scenarios in the WAVES project, „e-mentor” 2017, nr 3(70), s. 47–54,

- Kononowicz AA, Woodham LA, Edelbring S, Stathakarou N, Davies D, Saxena N, Tudor Car L, Carlstedt-Duke J, Car J, Zary N. Virtual Patient Simulations in Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. J Med Internet Res. 2019 Jul 2;21(7):e14676.
- Kononowicz AA, Hege I, Edelbring S, Sobocan M, Huwendiek S, Durning SJ. The need for longitudinal clinical reasoning teaching and assessment: Results of an international survey. Med Teach. 2020 Apr;42(4):457-462.
- Kulasegaram K, Mylopoulos M, Tonin P, Bernstein S, Bryden P, Law M, Lazor J, Pittini R, Sockalingam S, Tait GR, Houston P. The alignment imperative in curriculum renewal. Med Teach. 2018 May;40(5):443-448.
- Lang VJ, Kogan J, Berman N, Torre D. The evolving role of online virtual patients in internal medicine clerkship education nationally. Acad Med. 2013 Nov;88(11):1713-8.
- Long P. Siemens G, Penetrating the fog: Analytics in learning and education. EDUCAUSE review. 2011;46(5):30
- Lou, Y., Abrami, P. C., & d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. Review of educational research, 71(3), 449-521.
- Majernik, J, Szerdiová, L, Schwarz, D, & Zivcak, J. (2016, July). Integration of virtual patients into modernizing activities of medical education across MEFANET. In 2016 International Conference on Information and Digital Technologies (IDT) (pp. 186-189). IEEE.
- Maleck M, Fischer MR, Kammer B, Zeiler C, Mangel E, Schenk F, Pfeifer KJ. Do computers teach better? A media comparison study for case-based teaching in radiology. Radiographics. 2001 Jul-Aug;21(4):1025-32.
- Maier EM, Hege I, Muntau AC, Huber J, Fischer MR. What are effects of a spaced activation of virtual patients in a pediatric course? BMC Med Educ. 2013 Mar 28;13:45.
- Martini, N., Farmer, K., Patil, S., Tan, G., Wang, C., Wong, L., & Webster, C. S. (2019). Designing and Evaluating a Virtual Patient Simulation—The Journey from Uniprofessional to Interprofessional Learning. Information, 10(1), 28.
- Mayer RE. Applying the science of learning to medical education. Med Educ. 2010 Jun;44(6):543-9.
- Mayer A, Da Silva Domingues V, Hege I, Kononowicz AA, Larrosa M, Martínez-Jarreta B, Rodriguez-Molina D, Sousa-Pinto B, Sudacka M, Morin L. Planning a Collection of Virtual Patients to Train Clinical Reasoning: A Blueprint Representative of the European Population. Int J Environ Res Public Health. 2022 May 19;19(10):6175.
- McCarthy D, O'Gorman C, Gormley G. Intersecting Virtual Patients and Microbiology: Fostering a culture of learning. Ulster Med J. 2015 Oct;84(3):173-8.
- McEvoy M, Butler B, MacCarrick G. Teaching professionalism through virtual means. Clin Teach. 2012 Feb;9(1):32-6. doi: 10.1111/j.1743-498X.2011.00487.x. PMID: 22225890.
- Menendez E, Balisa-Rocha B, Jabbur-Lopes M, Costa W, Nascimento JR, Dósea M, Silva L, Lyra Junior D. Using a virtual patient system for the teaching of pharmaceutical care. Int J Med Inform. 2015 Sep;84(9):640-6.
- Morrissey, H., & Ball, P. (2014). Pharmacy subjects development. Currents in Pharmacy Teaching and Learning, 6(5), 736-744.

- Nascimento, F., Moore, M., Qasim, M., & Kung, D. (2021). NeuroLytes as a novel, virtual, case-based didactics targeted at medical students undergoing Neurology clerkship.(2900).
- Nasir J, Goldie J, Little A, Banerjee D, Reeves S. Case-based interprofessional learning for undergraduate healthcare professionals in the clinical setting. J Interprof Care. 2017 Jan;31(1):125-128.
- Naumann, F., Yang, J. L., Thai, T., Ford, C., & Polly, P. (2016). Virtual patient consultations and the use of an ePortfolio assessment to support student learning of integrated professional skills. Focus on Health Professional Education: A Multi-disciplinary Journal, 17(3), 69-81.
- Nordquist J, Sundberg K, Johansson L, Sandelin K, Nordenström J. Case-based learning in surgery: lessons learned. World J Surg. 2012 May;36(5):945-55.
- Norman G. Research in clinical reasoning: past history and current trends. Med Educ. 2005 Apr;39(4):418-27.
- Nunnally, B., & Farkas, D. (2016). UX research: Practical techniques for designing better products. " O'Reilly Media, Inc.".
- Peñuela-Epalza M, De la Hoz K. Incorporation and evaluation of serial concept maps for vertical integration and clinical reasoning in case-based learning tutorials: Perspectives of students beginning clinical medicine. Med Teach. 2019 Apr;41(4):433-440.
- Plackett R, Kassianos AP, Mylan S, Kambouri M, Raine R, Sheringham J. The effectiveness of using virtual patient educational tools to improve medical students' clinical reasoning skills: a systematic review. BMC Med Educ. 2022 May 13;22(1):365.
- Posel, N, Shore, B. M, & Fleiszer. Virtual patient cases: a qualitative study of the requirements and perceptions of authors. Int J Med Educ, 2012, *3*, 175-182.
- Posel N, Mcgee JB, Fleiszer DM. Twelve tips to support the development of clinical reasoning skills using virtual patient cases. Med Teach. 2015;37(9):813-8.
- Postma TC, White JG. Developing integrated clinical reasoning competencies in dental students using scaffolded case-based learning - empirical evidence. Eur J Dent Educ. 2016 Aug;20(3):180-8.
- Poulton, T, Balasubramaniam, Ch, Virtual patients: A year of change, Medical Teacher, 2011, 33:11, 933-937.
- Poulton T, Ellaway RH, Round J, Jivram T, Kavia S, Hilton S. Exploring the efficacy of replacing linear paper-based patient cases in problem-based learning with dynamic Web-based virtual patients: randomized controlled trial. J Med Internet Res. 2014 Nov 5;16(11):e240.
- Quail NPA, Boyle JG. Virtual Patients in Health Professions Education. Adv Exp Med Biol. 2019;1171:25-35.
- Quinn, Edel & Lehane, E. & Corrigan, Mark & Hill, Arnold & Redmond, H.. (2011). Evaluation of an interactive case-based learning textbook: a new approach to problem-based learning in surgery. Irish Journal of Medical Science. 180. S273-S274.
- Radon K, Carvalho D, Calvo MJ, Struempell S, Herrera V, Wengenroth L, Kausel G, Marchetti N, Rojas DS, Russ P, Hege I. Implementation of virtual patients in the training

for occupational health in Latin America. Int J Occup Environ Health. 2011 Jan-Mar;17(1):63-70.

- Riedel, J., Fitzgerald, G., Leven, F., & Toenshoff, B. (2003). The design of computerized practice fields for problem solving and contextualized transfer. Journal of Educational Multimedia and Hypermedia, 12(4), 377-398.
- Round J, Conradi E, Poulton T. Improving assessment with virtual patients. Med Teach. 2009 Aug;31(8):759-63.
- Sailer, M., Bauer, E., Hofmann, R., Kiesewetter, J., Glas, J., Gurevych, I., & Fischer, F. (2023). Adaptive feedback from artificial neural networks facilitates pre-service teachers' diagnostic reasoning in simulation-based learning. Learning and Instruction, 83, 101620.
- Sanders C, Kleinert HL, Boyd SE, Herren C, Theiss L, Mink J. Virtual patient instruction for dental students: can it improve dental care access for persons with special needs? Spec Care Dentist. 2008 Sep-Oct;28(5):205-13.
- Scherer A, Kröpil P, Heusch P, Buchbender C, Sewerin P, Blondin D, Lanzman RS, Miese F, Ostendorf B, Bölke E, Mödder U, Antoch G. Fallbasiertes interaktives "PACS-learning": Vorstellung eines neuen studentischen Lehrkonzepts für die Radiologie [Case-based interactive PACS learning: introduction of a new concept for radiological education of students]. Radiologe. 2011 Nov;51(11):969-70, 973-7.
- Seagrave MP, Foster-Johnson L, Waits JB, Margo K, Leong SL. Enhancing Examination Success: the Cumulative Benefits of Self-Assessment Questions and Virtual Patient Cases. Med Sci Educ. 2022 Aug 4;32(5):985-993.
- Shoemaker MJ, de Voest M, Booth A, Meny L, Victor J. A virtual patient educational activity to improve interprofessional competencies: A randomized trial. J Interprof Care. 2015;29(4):395-7.
- Smith SR, Cookson J, McKendree J, Harden RM. Patient-centred learning--back to the future. Med Teach. 2007 Feb;29(1):33-7.
- Smith BD, Silk K. Cultural competence clinic: an online, interactive, simulation for working effectively with Arab American Muslim patients. Acad Psychiatry. 2011 Fall;35(5):312-6
- Sobocan M, Klemenc-Ketis Z. Family Medicine Education with Virtual Patients: a Qualitative Study. Acta Inform Med. 2015 Aug;23(4):202-5.
- Sobocan, M., & Klemenc-Ketis, Z. (2017). Medical students' attitudes towards the use of virtual patients. Journal of Computer Assisted Learning, 33(4), 393-402.
- Steinert, Y. 2021. Staff Development. Dent, J. , Harden, RM, Hunt, D.(Eds.). A Practical Guide for Medical Teachers, 6th ed., Edinburgh: Elsevier, pp.351-9.
- Stevens A, Hernandez J, Johnsen K, Dickerson R, Raij A, Harrison C, DiPietro M, Allen B, Ferdig R, Foti S, Jackson J, Shin M, Cendan J, Watson R, Duerson M, Lok B, Cohen M, Wagner P, Lind DS. The use of virtual patients to teach medical students history taking and communication skills. Am J Surg. 2006 Jun;191(6):806-11.
- Sudacka M, Adler M, Durning SJ, Edelbring S, Frankowska A, Hartmann D, Hege I, Huwendiek S, Sobočan M, Thiessen N, Wagner FL, Kononowicz AA. Why is it so difficult to implement a longitudinal clinical reasoning curriculum? A multicenter interview study on the barriers perceived by European health professions educators. BMC Med Educ. 2021 Nov 12;21(1):575.

- Tausendfreund O, Braun LT, Schmidmaier R. Types of therapeutic errors in the management of osteoporosis made by physicians and medical students. BMC Med Educ. 2022 Apr 27;22(1):323.
- Trowbridge RL, Rencic JJ, Durning SJ, (ed). Teaching clinical reasoning. American College of Physicians; 2015.
- Tworek J, Coderre S, Wright B, McLaughlin K. Virtual patients: ED-2 band-aid or valuable asset in the learning portfolio? Acad Med. 2010 Jan;85(1):155-8.
- van der Vleuten CP, Schuwirth LW. Assessing professional competence: from methods to programmes. Med Educ. 2005 Mar;39(3):309-17
- Waldmann UM, Gulich MS, Zeitler HP. Virtual patients for assessing medical students--important aspects when considering the introduction of a new assessment format. Med Teach. 2008 Feb;30(1):17-24.
- Washburn M, Parrish DE, Bordnick PS. Virtual Patient Simulations for Brief Assessment of Mental Health Disorders in Integrated Care Settings. Soc Work Ment Health. 2020;18(2):121-148.
- Waldmann UM, Gulich MS, Zeitler HP. Virtual patients for assessing medical students--important aspects when considering the introduction of a new assessment format. Med Teach. 2008 Feb;30(1):17-24
- Wood DF. Formative assessment. In: Swanwick T, Forrest K., O'Brien B. Understanding medical education: Evidence, theory and practice., 3rd ed. 2019:361-73.
- Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. Med Educ. 2007 Dec;41(12):1173-7.
- Zary N, Johnson G, Fors U. Web-based virtual patients in dentistry: factors influencing the use of cases in the Web-SP system. Eur J Dent Educ. 2009 Feb;13(1):2-9.