Article

Virtual Laboratory Simulation in the Education of Laboratory Technicians—Motivation and Study Intensity

Lisbeth Elvira de Vries *†
Michael May‡

From the †Department of Technological Educations, University College Copenhagen, Copenhagen, Denmark 2200, ‡Department of Design and Communication, University of Southern Denmark, Kolding, Denmark 6000

Abstract

This study presents an evaluation of virtual laboratory simulation for educational use in the *AP Degree Programme in Chemical and Biotechnical Science* at *University College Copenhagen* in Denmark. The purpose was to test if, and how, virtual laboratory simulation could be applied to a practically oriented education such as the education of laboratory technicians—the aim being to motivate students and improve the education with new teaching tools. The study investigated how specific virtual lab simulation cases (Labster-cases) may stimulate motivation, study intensity, and learning among laboratory technician students. Altogether, 78 students evaluated different educational aspects of using virtual lab cases in relation to a 2-week course within gene technology. Overall, students were positive regarding the use of laboratory simulation as well as the specific cases tested. The study showed that virtual lab simulation seems to help laboratory technician students connect theory with practice and to visualize molecular processes as well as practical laboratory procedures and instrument techniques, however, it did also pose technical challenges. Furthermore, the study indicated that the use of virtual lab simulation cases can contribute to increased study activity as well as motivation. The overall conclusion of this study was that virtual lab simulation is an effective supplement to traditional teaching activities for the education of lab technicians. © 2019 International Union of Biochemistry and Molecular Biology, 47(3):257–262, 2019.

Keywords: *Laboratory technician students;* Academy Profession (AP) Degree Programme in Chemical and Biotechnical Science*; lab simulation case; Labster; gene technology; molecular cloning; next generation sequencing; NGS; teaching and learning techniques methods and approaches; biotechnology education*

Introduction

The technological development has contributed to new teaching tools and opportunities for capturing student's professional engagement in completely new and unconventional ways. Virtual laboratory simulation is an example of a blended learning activity [1, 2], which appears to strengthen learning outcomes when combined with traditional learning activities, including traditional hands-on exercises in the "real" laboratory [3–5]. Laboratory simulation has been tested and applied in several academic higher educations, mainly within technical and life sciences [5–8]. However, no studies have focused on the use of laboratory simulation specifically in practically oriented educations, such as the education for laboratory technicians.

In Denmark, the education for laboratory technicians is an academy profession (AP) degree programme in chemical and biotechnical science corresponding to level 5 according to the European Qualifications Framework (EQF) [9]. The programme is a short higher education within laboratory technology targeting employment in public or private analysis laboratories. It consists of a school part of 1½ year full time study and a trainee part of 1 year full time internship employment, typically in a university research group, a private biotech/medical company or in the food or chemical

Volume 47, Number 3, May/June 2019, Pages 257–262
**To whom correspondence should be addressed. Tel.: +4551380637; E-mail: lidv@kp.dk*
Additional Supporting Information may be found in the online version of this article.
Grant sponsor: University College Copenhagen, Department of Technological Educations
Received 21 October 2018; Revised 13 January 2019; Accepted 19 January 2019
DOI 10.1002/bmb.21221
Published online 12 February 2019 in Wiley Online Library (wileyonlinelibrary.com)

Box 1 Virtual laboratory simulation—*Labster* cases.
The virtual lab resembles a "real" laboratory (see illustration below top). With the mouse, the student moves around in the virtual lab and carries out several laboratory tests. A virtual lab assistant or a lab pad gives advice along the way. Virtual experiments are interrupted by multiple-choice questions, which must be answered correctly before proceeding (see Fig. 1 below to the right). The student has access to a Wikipediawith relevant background knowledge, and the student earns points for answering the multiple-choice questions. The teacher can follow the individual answers of students as well as whether students have completed the simulation. Animations of chemical or molecular processes pop up during the virtual experiments. Examples of the *Labster* cases used in this study are described below.

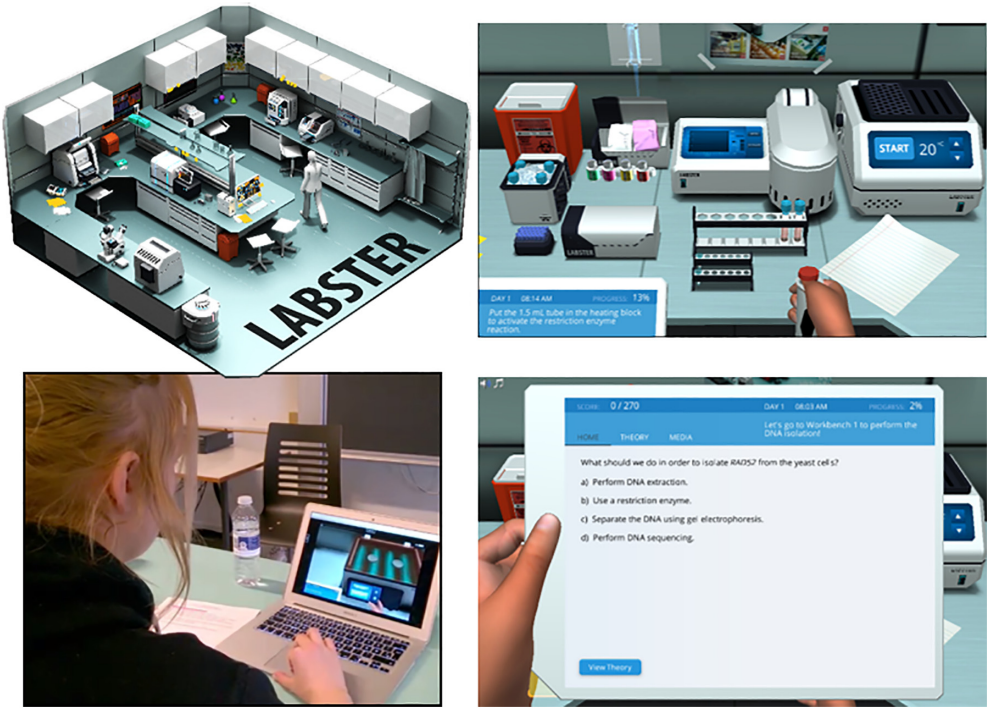

FIG 1 *Illustration of a virtual laboratory case. [Color figure can be viewed at wileyonlinelibrary.com]*

Next Generation Sequencing Case
The *Next Generation Sequencing* (*NGS*) case is relatively short (approximately 20–40 min to complete) [11]. The case is built around a high profiled research study, where the genome from an ancient extinct Palaeo-Eskimo was sequenced [12]. In the virtual simulation, students obtain a bone sample, extract human DNA, and perform DNA analysis (Illumina NGS sequencing). Besides, they are briefly introduced to DNA sequence analysis—in this case, the so-called Single Nucleotide Polymorphism (SNP) analysis, where specific SNPs are correlated with physical appearance (e.g., earwax thickness).

Molecular Cloning Case
The molecular cloning case [13] is longer than the *NGS* case—it takes approximately 2 h to complete. This case is also more complex. The simulation is built around a "story" about a researcher that seeks to test a protein (RAD52) for its hypothesized function in DNA repair. The simulation starts with an animation film where the researcher gets inspiration on how to set up the experiment using Green Fluorescent Protein (GFP) from jellyfish. During virtual experiments, students work with different molecular techniques, including DNA extraction, restriction enzyme digest, ligation, and transformation. They assemble an expression vector containing a specific regulator (TetOff), the *RAD52*, and the *GFP* genes and perform the actual analysis to establish if RAD52 plays an import role in DNA-repair.

industry. The school part is comprised equal parts theoretical classroom teaching and practical laboratory exercises, where students learn and train laboratory skills and procedures.

In this study, we present an evaluation of virtual laboratory simulation for educational use in the *AP Degree Programme in Chemical and Biotechnical Science* at *University College Copenhagen*[1] (*UCC*) in Denmark. The purpose was to test if and how laboratory simulation, developed by the Danish software company *Labster* [10] (Box 1), could potentially be applied to the education of laboratory technicians in order to motivate students and improve the education. The outset was, however, that laboratory simulation should in no way replace the hands-on practical training in the laboratory, which is central for educating lab technicians. Specifically, we investigated if and how virtual lab simulation cases from *Labster* may stimulate motivation and possibly learning among laboratory technician students compared with traditional teaching activities when applied in a theoretical course. In addition, we investigated if the use of lab simulation increased motivation for learning and study intensity among the students.

Methods

Virtual lab simulation cases were tested by laboratory technician students at *UCC* during 2014–2015. Specifically, student licenses for 1–2 *Labster* cases (see Box 1) were purchased. Both cases were tested and evaluated by students in an elective theoretical gene technology course, *Gene Technology II*, taught in the third and last school semester, just before students began their final internship year. *Gene Technology II* consisted of all together eight course-days with scheduled lectures as well as self-study activities (see Supporting Information section 1 for details). All students were informed that evaluation of their use of the virtual cases was voluntary and anonymous.

Evaluation of Potential Educational Use of Laboratory Simulation in the *AP Degree Programme in Chemical and Biotechnical Science*

In 2014, all together 31 students evaluated the use of the *Labster case*, *Molecular cloning* during two courses held in April and November, respectively. After an introductory session about course content and *Labster's* virtual laboratory, the students started working with the case during scheduled classes, where a teacher was present. Students were told to complete the case during self-study time (see Supporting Information Table S1.1). At the end of the course, students were encouraged to fill out a questionnaire (manually) evaluating the case and their perceived learning outcome from using lab simulation compared to other teaching activities/resources (see *Questionnaire of laboratory simulation 2014* in Supporting Information). Additionally, two students who appeared to be more active than usual when working with the virtual case were interviewed about their experience using the *Labster case* during the course in April 2014.

Evaluation of Laboratory Simulation Regarding Student's Study Activity

In April 2015, 29 students tested two *Labster cases* (*Molecular cloning* and *Next generation sequencing-NGS*) with the extended purpose of investigating whether the lab simulation cases had any effect on student's study intensity. Every morning during the course in, all students received an e-mail with a link to an electronic evaluation questionnaire regarding their study intensity (See *Questionnaire regarding preparation 2015* in Supporting Information). In relation to the topic, sequencing, the *Labster NGS case* was introduced. Students worked with the case during scheduled classes and self-study time. The *Labster case*, *Molecular cloning*, was integrated in a course assignment that the students were obliged to submit in order to pass the course. On the day of the deadline for completion of a simulation case, students also received an electronic evaluation questionnaire regarding the specific case (see *Questionnaire regarding Molecular cloning 2015* and *Questionnaire regarding NGS 2015* in Supporting Information). Finally, students received an electronic follow-up evaluation questionnaire just after completing the course (see *Follow up evaluation regarding study activity* in Supporting Information). All evaluation questionnaires were sent out and data were handled using the software Enalyzer [14]. On the last course-day, eight (randomly selected) students participated in a focus group interview where none of the course teachers were present.

Results

Laboratory Simulation is a Useful Supplement to Traditional Teaching Activities—It Helps Laboratory Technician Students Connect Theory with Practice

Overall, the majority of students were positive regarding the use of laboratory simulation as well as the specific *Labster* cases tested. Most students found the educational use of simulation to be a useful supplement to traditional teaching resources such as books, assignments, and lecturer presentations. In total, 84.3% answered that virtual lab simulation is a good supplement to existing/traditional teaching resources *"to a great extent"* or *"to a very great extent"*. Only 2.6% answered "to a *very low degree"* or "*to a low degree"*, and 15.7% answered "*neither nor*" (see *Supporting Informationsection 3*, including Supporting Information Fig. S3.1 for details).

In order to compare different teaching activities with regard to learning outcomes, students assessed the extent to which the different teaching resources supported their learning in terms of both professional and practical benefits. Here,

[1] Formerly *Metropolitan University College*. March 1st, 2018 Metropolitan University College and University College Capital merged into University College Copenhagen (UCC).

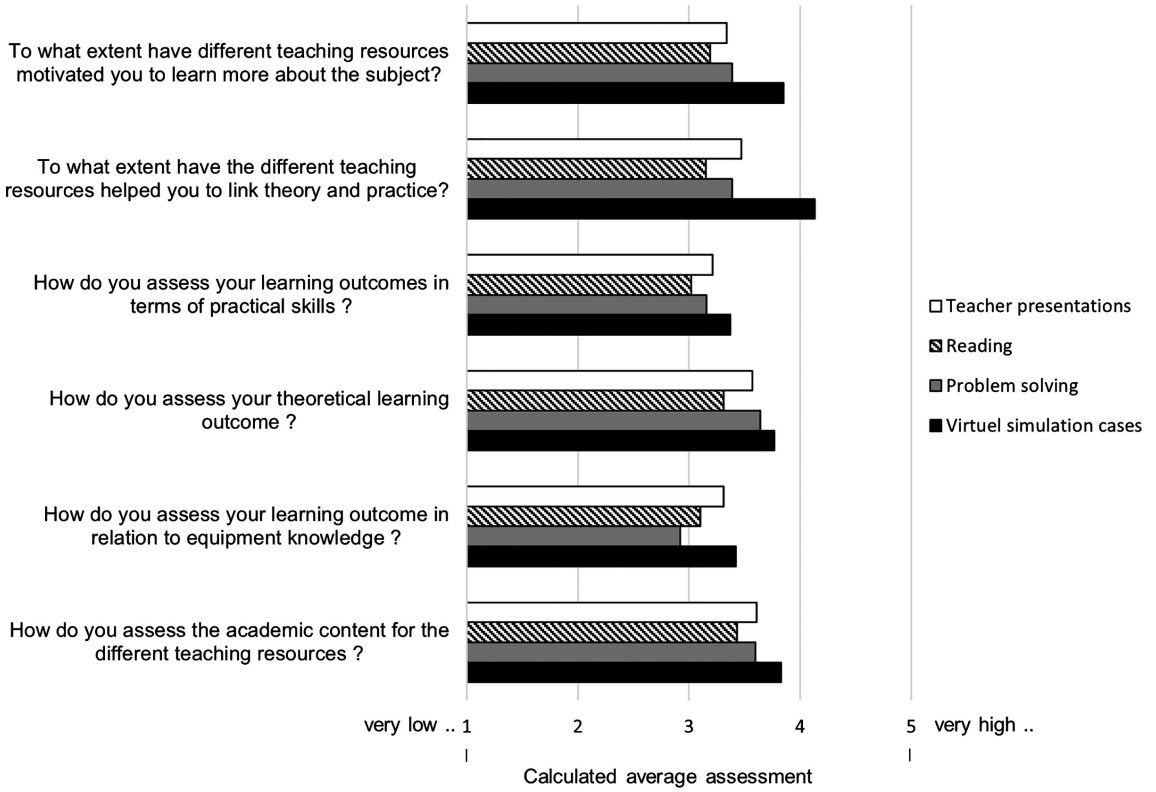

FIG 2 *Laboratory technician student's average assessments (on a scale of 1–5) of applied teaching resources in relation to the topics,* molecular cloning *and* sequencing *during the course,* Gene Technology II*, 2014–2015. Total student evaluation respondent rate were 82–83/107 = 77–78%. The question regarding* equipment knowledge *was only included in the evaluation of April 2015 (respondent rate was 48/58 = 83%).*

the lab simulation scored higher than other teaching resources (see Fig. 2 and Supporting Information Table S4.1). Especially, the use of simulation cases scored high in relation to the statement "*help to link theory with practice*". Besides this, several students recommended using laboratory simulation as a link that could create better correlation between theory and practice during their education. In the follow-up interview, a student stated, "*It was a very fun experience—it gives an overview and a picture of what to do in the real laboratory*". Many students suggested lab simulation as a regular preparation resource that could be used prior to hands-on lab exercises.

Lab Simulations Help Students Visualize Molecular Processes and Instrument Techniques, but they also Pose Technical Challenges

Students were asked to write what they thought was good and what was less good about the lab simulation. Especially, features of the lab simulation related to visualization as well as the case itself (the story and the overall set-up) were emphasized as good by many students (Supporting Information Fig. S5.1). On the negative side, many students highlighted technical issues as something that was less good and could be improved. Many students mentioned that the simulation included too many *mouse clicks*, which they found tiresome. They found it annoying that they could only use one hand in the virtual lab and therefore had to *click* back and forward several times in order to complete a task—for example, when picking up more plates to put in an incubator. Besides, several students wrote in the evaluation that they would prefer to work with simulation cases in Danish (Supporting Information Fig. S5.1). In both interviews (2014 and 2015), students described that the lab simulations helped them visualize practical procedures in the laboratory as well as molecular and chemical reactions, which occurred during the experiments. For example, a student stated, "*It was a better way to prepare than to read a guide - It's easier to understand things when you work with them, than when you read about them, and it gives you* images *of the work.*" (interview 2014). In the focus group interview 2015, several students said that the virtual simulations and especially the incorporated animations helped them visualize the theory as well as elements of the practical laboratory work, which gave them better or increased learning. Thus, apparently there are two aspects of how the visualization of the simulation cases help the students in their learning: 1) Animation that visualize molecular processes and thereby help student to understand the theory, and 2) The actual virtual lab with visualization of equipment and techniques that help students perform practical procedures in the hands-on laboratory.

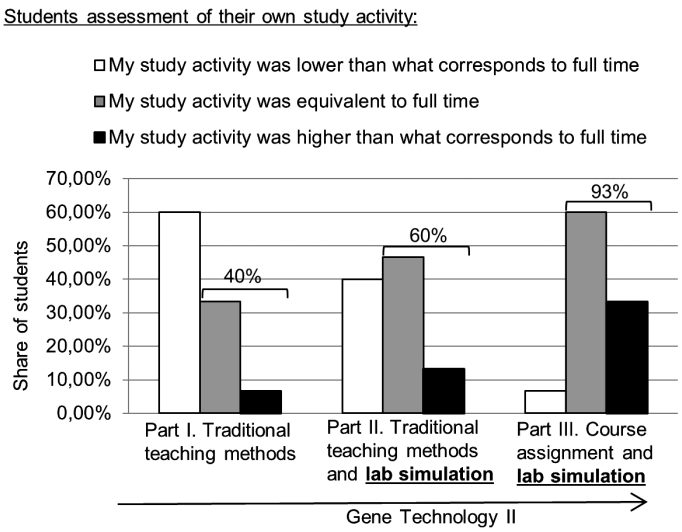

FIG 3

Laboratory technician student's assessment of their own study activity during a theoretical course in gene technology where different teaching activities were used. The course (8 course days) is divided in to three parts (I-III). Part I focused on different gene technology techniques and included traditional teaching resources such as books, assignments, and teacher presentations. Part II focused on DNA sequencing and included traditional teaching resources as well as a virtual laboratory simulation case (the NGS Labster case*). Part III included a course assignment within the entire course curriculum and a lab simulation case (The* Labster Molecular Cloning case*). (Data originates from the follow up questionnaire survey April 2015; Response rate 15/29 = 52%).*

Virtual Laboratory Simulation Contributes to Increased Study Intensity among Laboratory Technician Students

The evaluation from 2015 showed that virtual lab simulation can influence students to be better prepared and to spend more time on their overall study activity as well as on preparing for scheduled classes. Approximately, 60%–93% of the students indicated that their study activity was equivalent to or higher than a full-time study for parts of the course, which included simulation cases (see Fig. 3). Whereas only 40% of the students stated to work full time or more for the course part, which did not include a virtual exercise, but rather focused on traditional teaching resources such as textbook reading, lectures, and small assignments (Fig. 3). Besides, in the daily evaluations, a larger proportion of students stated to be "*very*" or "*fully prepared*" (84%–94%) and to spend more time preparing for classes on course days, which included deadlines for the completion of lab simulations and the submission of a course assignment, compared to course days focusing on traditional teaching resources (19%–65%) (see Supporting Information Fig. S6.1a and b). However, it could not be ruled out that the measured tendency was affected by other factors, such as different curriculum size for the individual days, different lecturers, and coincidence with other deadlines.

In the evaluations of the two simulation cases, students were asked directly to what extent the simulation case had influenced their work efforts. Here, 29 and 20% answered that they had spent more time than usual for the *NGS* case and the *Molecular cloning* case, respectively (see Supporting Information Table S6.1). More than 50% claimed to have worked as usual for both cases. Approximately 13 and 28% answered that they had worked less than usual for the *NGS* case (in relation to the topic sequencing) and the *Molecular cloning* case (in relation to the course assignment), respectively. Thus, apparently the two cases (or how they were used) differed with respect to how they might have affected the work effort of the students.

In the focus group interview, students explained that they generally prepared more for lecturers that included assignments (e.g., virtual exercises or the course assignments). A student described it as follows: *"It takes longer to read and solve assignments for the next day than if you only have to read. When I also have to solve assignments, I have to read in a different way than if I just have to read something that is being presented by the lecturer"*.

Discussion

Altogether, the evaluations showed that laboratory simulation cases are a good supplement to traditional educational tools, which appears to support laboratory technician students in their learning. Specifically, virtual simulation appears to help students visualize laboratory procedures as wells a molecular theory, and possibly thereby help students create a link between theory and practice in the hands-on laboratory. Besides, the evaluations showed that lab simulation can contribute to increased study activity and motivation among laboratory technician students. However, a clear link between the use of virtual exercises and student's perception of their own study intensity was not shown. Evaluation of the individual virtual simulation cases indicated that content, length, and specific practical application may have influenced the students estimations of whether a simulation had impact on their work effort or not.

Overall, the conclusions of the study are consistent with former studies of *Labster* cases in relation to different university educations at bachelor or master level [3–5, 8]. Virtual laboratory simulation has proven to be a very promising teaching tool because it accommodates students at different academic levels, and students are constantly activated during the simulation, which includes a combination of virtual lab work, animations, quiz questions, and background theory [4]. The reported evaluation has led to virtual lab simulation being implemented in the AP degree programme in chemical and biotechnical science at *UCC in Denmark*.

Overall, virtual laboratory simulations are used in three different ways: (i) as a replacement for hands-on exercises,

(ii) in preparation for hands-on exercises, or (iii) in addition to purely theoretical courses [4].An important advantage of the first application mode (i) is that it is usually cheaper than hand-on exercises, which requires expensive equipment, chemicals as well as working hours. For example, the cost for virtual lab simulations from Labster ranges between US$10 for one simulation to $199 for full access per student per term [15]. Besides, students have access to do the virtual experiments when it suits them. In this evaluation, we focused on the last mode (iii), as virtual lab training can or should not replace training in the hands-on laboratory for technician students. However, both tested cases are currently applied in a course that consists of both theory and traditional laboratory exercises, but because the education does not possess DNA sequencing equipment (*Illumina*), the first mode of application (i) has proved appropriate in relation to the *NGS* case. For the *NGS Labster* simulation, the case is used as a supplement to theory regarding DNA sequencing with the intention to give the students an introduction to *NGS* sample preparation as well as a visual experience of loading a *NGS* sequencing equipment—thus contributing to the theory/practice dimension of the education. The *Molecular cloning* case is currently applied alongside a practical cloning exercise, which includes similar molecular techniques including DNA extraction, restriction enzyme digest, ligation, and transformation. However, the virtual and the practical exercises have quite different overall focus and strategy, and the molecular technical protocols used to do also differ. Thus, the *Molecular cloning* case is used as an example of an additional cloning experiment. In the future, we aim at integrating a simulation case as actual preparation for a specific hands-on exercise (application (ii)) according to recommendations of the students obtained in this evaluation as well as recent studies, which concluded that virtual laboratories have potential to improve university student's preparation for lab exercises [4, 8].

Acknowledgment

We want to thank lecturer Torben Skou and academic secretary Fie Isager for support in conducting the focus group interview and formulating the evaluation questionnaires. We also want to thank Head of Academy Profession and Bachelor's Degree programmes Lise Rølmer Nissen for the idea of testing the connection between study intensity and the use of lab simulation.

Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

[1] Conole, G. (2013) Designing for Learning in an Open World, Springer, New York, NY.

[2] May M., Achiam M. F. (2014) Virtual laboratories in chemistry, biochemistry & molecular biology. Accessed on 13 January 2019. Available from: https://www.academia.edu/4312334/Virtual_Laboratories_in_Chemistry_Biochemistry_and_Molecular_Biology.

[3] de Jong, T., Linn, M. C., Zacharia, Z. C. (2013) Physical and virtual laboratories in science and engineering education. Science 340, 305–308.

[4] Skriver, K., Dandanell, G., von Stemann, J. H., May, M. (2015) Udfordringer ved undervisning i enzymer – Bidrag fra det virtuelle laboratorium. MONA. 1, 49–65.

[5] Bonde, M. T., Makransky, G., Wandall, J., Larsen, M. V., Morsing, M., Jarmer, H., Sommer, M. O. A. (2014) Improving biotech education through gamified laboratory simulations. Nat Biotechnol. 32, 694–697.

[6] Makransky, G., Bonde, M. T., Wulff, J. G. S., Wandall, J., Hood, M., Creed, P. A., … Nørremølle, A. (2016) Simulation based virtual learning environment in medical genetics counseling: An example of bridging the gap between theory and practice in medical education. BMC Med Educ. 16, 1–9.

[7] Makransky, G., Thisgaard, M. W., Gadegaard, H. (2016) Virtual simulations as preparation for lab exercises: Assessing learning of key laboratory skills in microbiology and improvement of essential non-cognitive skills. PLoS One 11, e0155895.

[8] Dyrberg, N. R., Treusch, A. H., Wiegand, C. (2017) Virtual laboratories in science education: students' motivation and experiences in two tertiary biology courses. J Biol Educ 51, 358–374.

[9] European Qualifications Framework (EQF). Accessed on 13 January 2019. Available from: https://ec.europa.eu/ploteus/content/descriptors-page.

[10] Overview of Labster's simulation. Accessed on 13 January 2019. Available from: https://www.labster.com/simulations/.

[11] Labster Next Generation Sequencing Virtual Lab. Accessed on 13 January 2019. Available from: https://www.labster.com/simulations/next-generation-sequencing/.

[12] Rasmussen, M., Li, Y., Lindgreen, S., Pedersen, J. S., Albrechtsen, A., Moltke, I., Willerslev, E. (2010) Ancient human genome sequence of an extinct Palaeo-Eskimo. Nature 463, 757–762.

[13] Labster Molecular Cloning Virtual Lab. Accessed on 13 January 2019. Available from: https://www.labster.com/simulations/molecular-cloning/.

[14] The Software Enalyzer. Accessed on 13 January 2019. Available from: https://www.enalyzer.com/.

[15] Jones, N. (2018) The virtual lab. Nat Outlook - Sci Technol Educ 562, 5–7.