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Digital Game-Based Support for Learning the Phlebotomy Procedure in the Biomedical Laboratory Scientist Education

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Abstract: Practice-based training in education is important, expensive, and resource-demanding. Digital games can provide complementary training opportunities for practicing procedural skills and increase the value of the limited laboratory training time in biomedical laboratory science (BLS) education. This paper presents how a serious game can be integrated in a BLS course and supplement traditional learning and teaching with accessible learning material for phlebotomy. To gather information on challenges relevant to integrating Digital Game-Based Learning (DGBL), a case was carried out using mixed methods. Through a semester-long study, following a longitudinal, interventional cohort study, data and information were obtained from teachers and students about the learning impact of the current application. The game motivated students to train more, and teachers were positive towards using it in education. The results provide increased insights into how DGBL can be integrated into education and give rise to a discussion of the current challenges of DGBL for practice-based learning.

Keywords: Digital Game-Based Learning (DGBL); phlebotomy; blood sampling; serious games; laboratory; longitudinal study; training; teaching; learning

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1. Introduction

Digital Game-Based Learning (DGBL) has gained increased interest for learning and training in higher education for its potential benefits such as increased engagement, self-paced learning, automated feedback, and allowing solutions for flipped classrooms [1,2].

There are several educational programs, e.g., biomedical laboratory science (BLS) and other health-care educations, where practical learning is essential [3–5]. For the phlebotomy (venous blood sampling) procedure, students need practical training to achieve the necessary knowledge and skills for their future work. It is an important skill to learn for several professions, while also being a heavily resource-constrained learning activity experiencing challenges in planning sufficient phlebotomy training sessions in the laboratories. Most of the errors regarding blood analysis stem from simple pre-analytic mistakes such as incorrect handling of sample tubes, misidentification of patients, and mislabeling of samples [6,7]. Therefore, new possibilities to train more and explore additional ways for students to practice procedural or skills knowledge to train to perform phlebotomy is important. While DGBLs have promising benefits in this regard, implementing the games can also present challenges, such as knowing how to implement these effectively, use the underlying technology, meet requirements from the educational system, and obtain suitable games [8] from the teachers, or handle the lack of engagement from the students' perspective.

The goal of this paper is to provide insight into how DGBL can support health care students in learning the phlebotomy procedure. While an important aspect of learning to perform phlebotomy correctly is skill-based, this cannot be achieved without understanding the whole process surrounding the main activities [9]. An earlier/better understanding of necessary procedural elements can help the students to reach higher levels of skill acquisition [10]. By helping the students experience how all parts of the procedure relate to each other, DGBL can be a valuable tool for providing opportunities for meaningful learning [11,12]. Thus, this study focuses on how DGBL can better support gaining procedural knowledge compared to traditional elements in BLS education. While skill-based training is not completely outside its scope, this paper differentiates skill-based learning from procedural learning and the focus is on procedural learning.

Defining such a supportive game is challenging as there are many choices associated with the development of digital game applications, e.g., technologies and techniques [13], and adaptivity [14]. Many previously developed games are not in use. To ensure that the games are actually used in education necessitates integration, not only to existing laboratory facilities and other technologies but also to actual learning goals [15]. Such mapping of game elements to the learning goals can be difficult [16,17]. This project investigates how to further develop a 2D game supporting learning the phlebotomy process [18] and how to successfully integrate it into education. Through this game, students can train at their own pace and prepare for real-life laboratory exercises and learn from automated feedback provided by the game. They can play through different phlebotomy scenarios to familiarize themselves with the procedures and learn-by-doing. To gather data and information, a longitudinal case study was carried out, following the integration of a serious game in BLS education.

This longitudinal study was negatively influenced by the COVID-19 pandemic. It was planned as an experimental study during spring 2020 following groups in a class using a game to learn the phlebotomy process with a goal of differentiating their results from groups who do not use the game. While it was not possible to carry out the originally envisioned plan, the study was adapted to COVID-19 premises, and carried out with some changes, i.e., missing the last laboratory observation, and performing digital data collection instead of focus group interviews. The results, and direct observations argue for the added benefit of digital technologies for practice-based training. While this is in accordance with studies from other fields [19,20], this paper contributes to a better understanding of activities and their effects during the implementation process. It also contributes to urging the need to determine new possibilities to learn practice-based training with the help of technologies that allow for higher experiences and immersiveness [21].

2. Background

2.1. Challenges for Learning Phlebotomy

Following a correct blood sample procedure is crucial in order to ensure that the quality of the biological specimens is satisfactory [22–25]. In Norway, at clinical hospitals, phlebotomy (venous blood sampling) is still mainly undertaken by BLS health care professionals. However, nowadays, an increasing number of hospitals decentralize the blood sampling work to clinical departments due to cost efficacy. Hence, practicing the blood sampling procedure is important not only for BLS students but also for nursing students. Traditionally, in Norway, nursing students receive little training or opportunity to practice the phlebotomy procedure, and if they are working at smaller diagnostic clinics, they can not necessarily practice it often enough. Currently, teaching phlebotomy in health care education encounters several challenges, such as limited time, access to necessary resources, or laboratory facilities. Additionally, a major challenge is to reproduce the conditions (or elements of the conditions) of an authentic working environment at campuses [18,26–28]. Variations between laboratory environments makes it necessary for BLS professionals and nurses to learn to perform the procedure independently of the location or the tradition at workplaces. Some nurses or BLS students learn only in the laboratories at their institutions. Performing phlebotomy at various locations may increase the confidence of students when performing the procedure. Without utilizing digital technology, practice-based training at multiple places is seldom achievable for many students.

The education of health professions is constantly changing, depending on new requirements from today's complex society. We need to focus more on distance education [21], and utilization of supportive technologies such as serious games, gamification, virtual reality, and virtual simulation, here used under the overarching term of Digital Game-Based Learning (DGBL). All these new technologies contribute to DGBL with the overall vision to support practice-based learning [29,30].

While a vast number of different supportive technologies exist, few solutions are actively used in classrooms and considered adequate to help reach learning goals, except computers and mobile phones. While there are several evaluations addressing the effectiveness of some specific digital tools, these are often feasibility studies in research laboratories and are seldomly implemented in a real usage context [15]. The implementation of such new technologies as virtual reality, serious games, or mixed reality technologies can be complex, especially for situations where both the users and stakeholders responsible for use do not have the technical competence necessary to adjust the technologies to the usage context [31].

2.2. Tools Supporting Phlebotomy Learning

Different strategies are applied when teaching BLS students the procedure of phlebotomy. Lectures are used to introduce concepts and explain the different steps of the phlebotomy procedure. Students are also given written and illustrated explanations of the procedure with supplementary information for all steps in the procedure. Demonstrations are given both physically, and as videos demonstrating all the steps in the procedure. After students have heard about, read about, and seen the procedure, they start to practice performing venous blood sampling on each other in the school laboratory. The course instructors rotate through students, supervising them and giving them continuous feedback on their performance. Some students are also offered use of a mannequin arm for practicing, without supervision, necessitating the students to self-assess. When students can repeatedly perform the procedure, a routine can be established, and their self-confidence can increase. However, the number of times the students can perform the venipuncture on each other is limited, which restricts the number of repetitions in realistic conditions.

There are currently a variety of different serious games and virtual simulations for phlebotomy learning:

Prøvetakingsmesteren is a Norwegian phlebotomy learning game that is a part of the "Attensi Skills" mobile application [32]. It features several categories to "master". In the game, virtual avatars can interact with users. It is primarily focused on assessing the knowledge of a user that has already been through the material and estimate what they learnt. The gameplay is similar to other games in the "Attensi Skills" application, and supports goal achievement with gamification elements such as quizzes, finding the right combination of words, etc.

Labster is a learning game for PC [33]. It contains an assortment of learning scenarios for different domains of science, including some modules where the player analyses blood samples. It does not contain elements regarding the blood sampling procedure itself.

360-Phlebotomy is a Virtual Reality (VR) serious game utilizing 360°-images and -videos of real hospitals and laboratories to create authentic learning environments [34]. By using 360°-footage there is a trade-off between visual realism and movement, but changing the context may contribute to learning, not only the phlebotomy procedures, but also differences in environments for blood sampling.

VIDA-Nursing is a VR simulation for learning vacuum blood collection on adults [35]. It uses hand-tracking as the primary input mechanic.

Laerdal Virtual Phlebotomy is a discontinued product from Laerdal Medical [36]. It contains a haptic input device that connects to a PC and is intended to be used with a 2D screen. Studies have shown an improvement in completion time and error score by performing training in this way [37].

CathSim is a non-immersive VR simulator used for training needle stick procedures such as IV cannulation and phlebotomy [38]. It consists of a dedicated haptic input device that mimics the force resistance when puncturing a vein and connects to a PC to provide supporting visuals and performance data.

Certainly, there can be several other different tools supporting phlebotomy learning. Many of these tools can be beneficial for a particular application area, while there are others for some others. For non-experts, it can be difficult to navigate and choose between the tools. Developing their own applications is also an approach that universities utilize. These can have their benefits, since universities can steer the design and development of the tools, and these can be more flexible, but they are often limited compared to solutions offered by professional companies who often have multiple customers as sources of funding.

3. Materials and Methods

This study presents a case using a mixed methods approach with the goal of gaining insight into multiple facets of using serious games in BLS education. The serious game StikkApp [18] was previously tested and further developed in several iterations [26,27] with input from teachers and students. StikkApp is a serious game supporting learning phlebotomy for BLS students, developed by the participating university. A longitudinal, and interventional, cohort research study was planned to investigate how the game can be systematically used in teaching and learning. Quantitative and qualitative methods were used to collect students' (and teachers') perceptions and to investigate the potential learning effects of using the game. Data was gathered using questionnaires and information was gathered via observations and semi-structured interviews. The research study lasted one semester (5 months), allowing the participating students and teachers to use the app in their everyday learning environment; in laboratories, at the school facilities, during travel, and in their homes. Students provided detailed feedback on app features. The study design, study timeline, and time points for data collection are illustrated in Table 1.

Table 1. Study timeline for the intervention, including timepoint for data collection.

Date (Course Week)	Event	Data Collection/Action	Target Group	Control Group
20 January 2020 (Week 1)	Access to StikkApp	Online in a Web browser	20 students	34 students
21–23 January 2020 (Week 1)	First phlebotomy training	Questionnaires (Baseline)	20 students	34 students
3–5 March 2020 (Week 6)	Sixth phlebotomy training	Questionnaires (6-week)	20 students	34 students
20 May 2020 (Week 18)	Summative exam	Comparative results	19 students	36 students
18 August 2020 (Week 31)	Focus group interview	Semi-structured recorded video conference	4 students	

The game was introduced to approximately 1/3 of the first-year students in a 10 ECTs course (BIO126) spring of 2020. Next, further details of the study design are presented.

3.1. Implementation of StikkApp

StikkApp is a browser game that was implemented in Unity and deployed for WebGL. Previous versions have been featured in other studies [18,26,27]. The game is in 2D with a combination of quiz sections and interactive parts.

To help players in learning of the procedure and when reviewing, the game contains a section where the player can read important background information regarding the phlebotomy procedure.

The game takes the player through all parts of the phlebotomy procedure. A diagram of the game flow of the application can be seen in Figure 1.

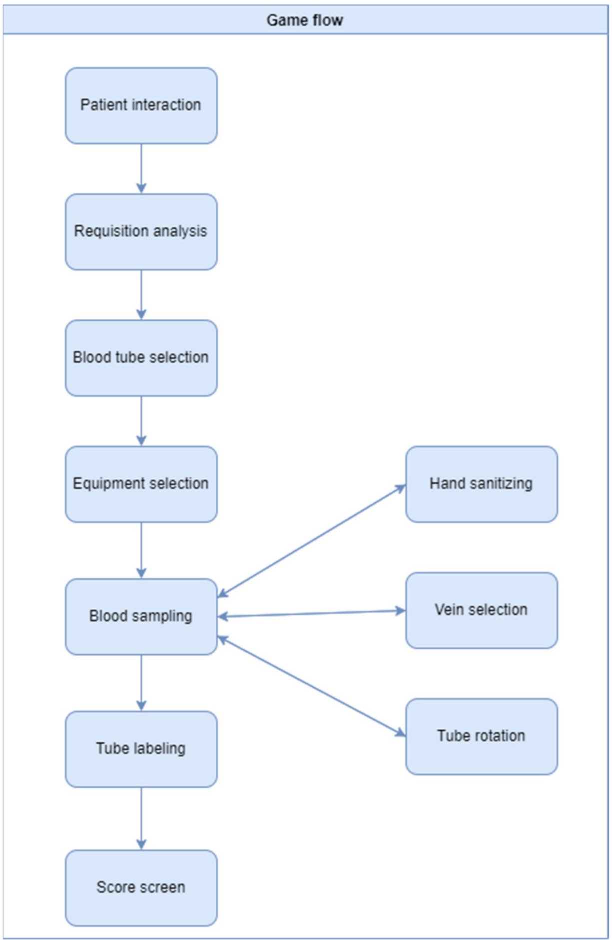

Figure 1. The flow of game scenes in StikkApp.

The first part of the game is a quiz-section where the player must correctly choose the appropriate ways of interacting with the patient regarding patient identification and empathic behavior. Afterward, a requisition form indicating the required analyses is presented to the player. The player must use the information from the requisition in the next step to deduce and pick the correct type and number of blood tubes to use. Next, the player must choose the necessary equipment for the procedure, such as a cannula and disinfectants. Following up is a section where the blood tubes and equipment must be chosen in the correct order of use. Some of the objects send the player to special interactive sections related to the object where the player must accurately rotate the sampling tube, sanitize hands, identify veins, etc. Afterward, the player must play through a section of finishing work where they must correctly label each tube. In the end, the player receives an overall score as well as a score for each section.

Various design decisions were made to facilitate learning. Instant feedback is provided to the player both visually and in the form of representative sounds that are played when the player does something correct or wrong. Videos are incorporated into some sections to show proper technique. Specialized interactive sections that attempt to mimic the physical action were created to reinforce learning. In the quizzes, common mistakes are included as the wrong options, intended to familiarize students with them. Explanations for correct answers are also exemplified to provide additional context. Samples from the game can be seen in Figure 2.

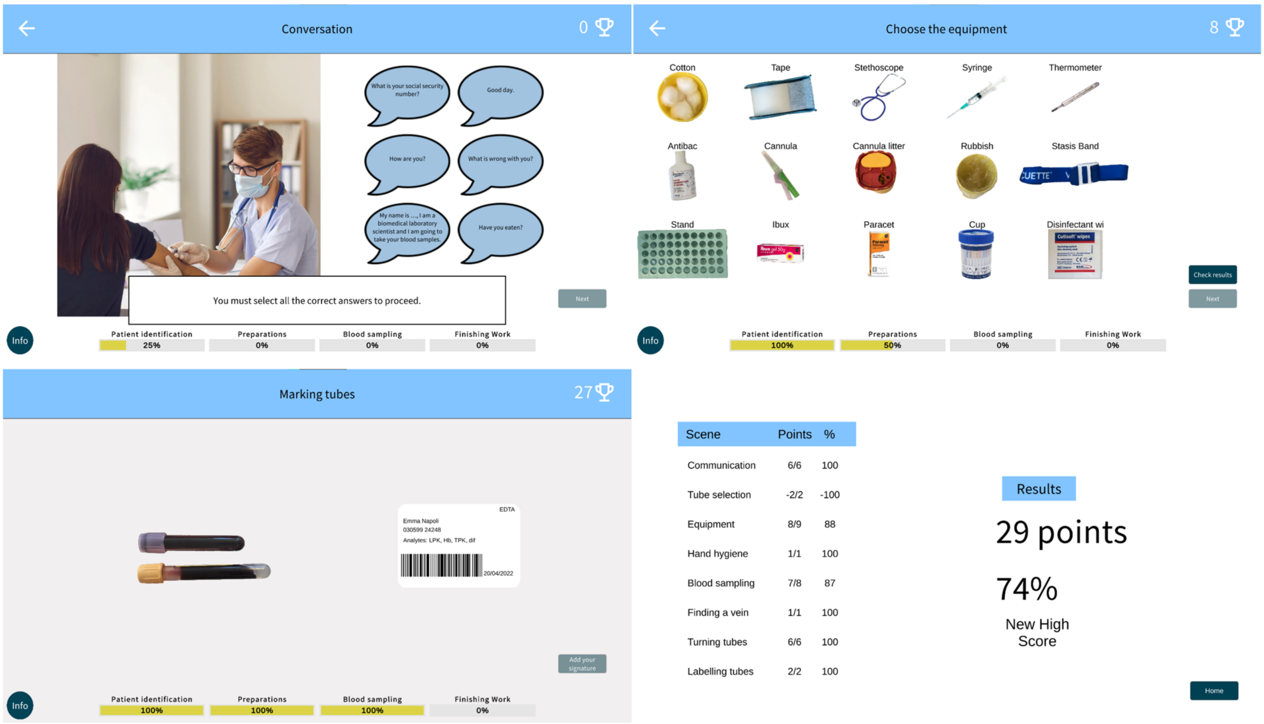

Figure 2. Screenshots from StikkApp showing the following game scenes: Conversation (**top left**), Blood sampling (**top right**), Tube labeling (**bottom left**), Scoring (**bottom right**).

The game was hosted online, where the test group could access it through a web browser on their computer. No download was necessary. Access to the application was provided 2 days before their first practical phlebotomy training.

A disclosure of invention for the application has been submitted. Thus, the source code of the application cannot be shared at the present moment.

3.2. Ethical Considerations

The study received approval from the Norwegian Centre for Research Data (NSD; number 192536) and followed the rules of the Declaration of Helsinki of 1975. All participants provided informed written consent. All data collected from participants was anonymized before data storage, analysis and a scrambling key were stored separately from the data material.

3.3. Study Population

First-year students enrolled in a course in Medical Laboratory Technology (10 ECTs) were contacted by the research group for recruitment. For a total of 54 students, all the enrolled students partook and were randomized to either the test group (gained access to StikkApp) or the control group (not given access to StikkApp). All 54 students completed the laboratory training, whereas 50 students completed the final exam of the course. StikkApp user group had median age 20.5 years (range 19–44 years), and gender distribution was 19 female and one male. The control group had a median age of 21 years (range 19–41 years), and gender distribution was 21 females and five males.

3.4. Data and Information Collection

The learning effect and the students' motivation and preferences were compared with a control group consisting of the remaining 2/3 of the students in the same course.

Comprehensive feedback was gathered from students regarding previous experiences of using serious games, how they experienced using StikkApp, and their future views of using games and digital technologies in their education. Summative assessment results were collected and analyzed for potential differences between groups.

For the reason of challenges due to COVID-19, the student group interview was conducted at the start of the following semester.

3.5. Questionnaires

Two questionnaires (non-validated) using closed questions and 7-point Likert scales with a few open questions for added context were undertaken at baseline and after the 6 weeks with phlebotomy training. The Likert scale used assumes that the strength/intensity of an attitude is linear on a continuum from strongly agree to strongly disagree.

The results of the questionnaires are presented using color-coded divergent stacked bar charts or bar charts. Due to small sample sizes, unpaired Mann–Whitney U-tests were performed to statistically compare the two sample points for each group and across group comparisons.

3.6. Summative Assessment (Written Exam)

A summative written assessment (final exam) to evaluate student learning was undertaken approximately 8 weeks after the last laboratory course day. One of the final exam questions (question 6a) was dedicated and highly relevant for our StikkApp study. Post ordinary censorship (independent from ordinary censorship), the answers from students were scored by an experienced sensor. The sensor was blinded (the two cohorts were mixed, and no information was given) to avoid influenced outcomes. The scores for the two cohorts were then evaluated and compared.

3.7. Semi-Structured Interviews

A semi-structured focus-group interview was conducted after the summative exam. 4 volunteering students from the target group participated, and it lasted for 1 h and 20 min. The interview was structured in 5 phases:

1. Introduction
2. Information
3. Previous experiences
4. Key questions
5. Summary

The interview guide can be found as Document S1 in Supplementary Materials.

The two interviewers paid close attention to conversational tone and pauses and asked follow-up questions, where needed, to probe more deeply into the participants' responses and to minimize any respondent bias. The focus-group interviews were undertaken by two researchers, with one researcher leading the interview and the other taking detailed notes. Interviews were performed virtually on Zoom—a videoconferencing platform—and recorded. The recordings were manually transcribed to be analyzed. After utilizing systematic text condensation [2], descriptions and concepts were developed from the interview questions. After completing the study, codes from interviews and the open-ended questions in the survey were compared and then eventually harmonized to derive the results presented.

3.8. Statistical Analysis and Software

Data were analyzed using GraphPad Prism version 6 for Windows, GraphPad Software, La Jolla, CA, USA. Mann Whitney U was used across cohort comparisons (two independent groups). The Wilcoxon test was used for within cohort comparison (matched samples). The results showing statistically significant differences are clearly indicated in the text.

4. Results

4.1. Questionnaire Results

4.1.1. Comparability across Groups and Overall Learning Preferences

Our results indicate that students' learning preferences across the StikkApp users (target group) and non-StikkApp users (control group) are similar (see Figure 3), hence indicating comparability. Practical laboratory courses and lectures were preferred over reading the curriculum textbook (see Figure 3). The choice "Other" was followed by an open comment textbox, and the following keywords were mentioned: (i) video/YouTube, (ii) talking to others, (iii) Google/internet, (iv) quiz, and (v) own writing (recall); additionally, the user group mentioned (vi) StikkApp.

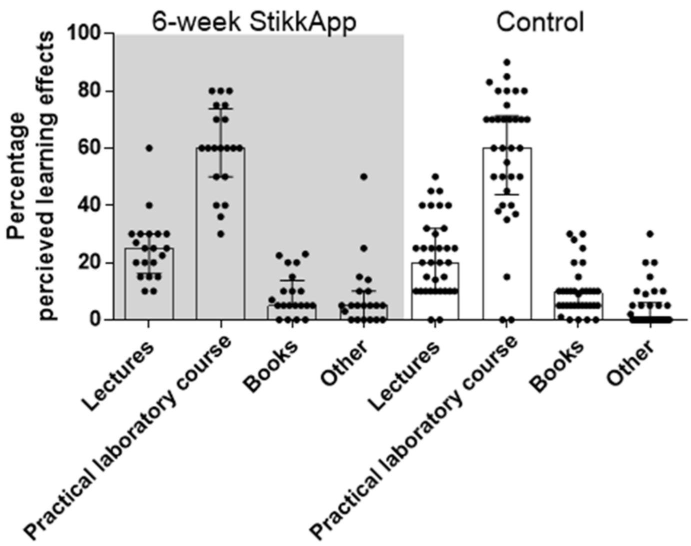

Figure 3. Results from questionnaires presenting how StikkApp users (target group) and non-StikkApp users (control group) perceived the learning effects measured on a forced fixed sum comparison rating amount (100%). Results are presented in a bar chart (mean with standard deviation).

When specifically asked, the majority of the students believed that Digital Game-Based Learning (DGBL) is a good learning strategy, which was also confirmed after using StikkApp for 6-weeks (see Figure 4).

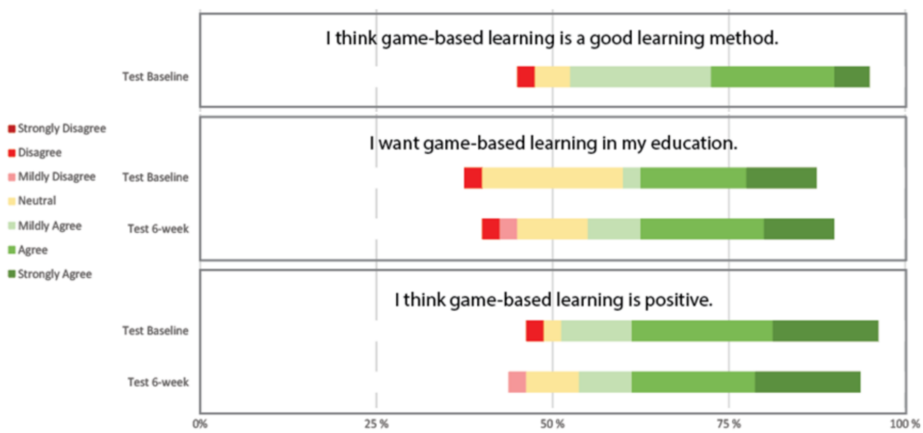

Figure 4. Results from two questionnaires administrated to the StikkApp user group (at baseline and/or after the 6-week period with phlebotomy training). Results are presented by a seven-point Likert scale by using color-coded divergent stacked bar chart.

4.1.2. StikkApp User Perspectives

The StikkApp users in this study were overall positive towards DGBL (see Figures 4 and 5). From the baseline to the 6-week questionnaire, their responses remained much the same (see Figures 4 and 5), possibly indicating that StikkApp fit their expectations of a learning game. Most students agree (ranging from mildly to strongly) that StikkApp is an engaging and effective learning method, to be used when preparing for and learning about performing the phlebotomy procedure. This is true for both baseline and after the 6-week use of StikkApp (see Figure 5).

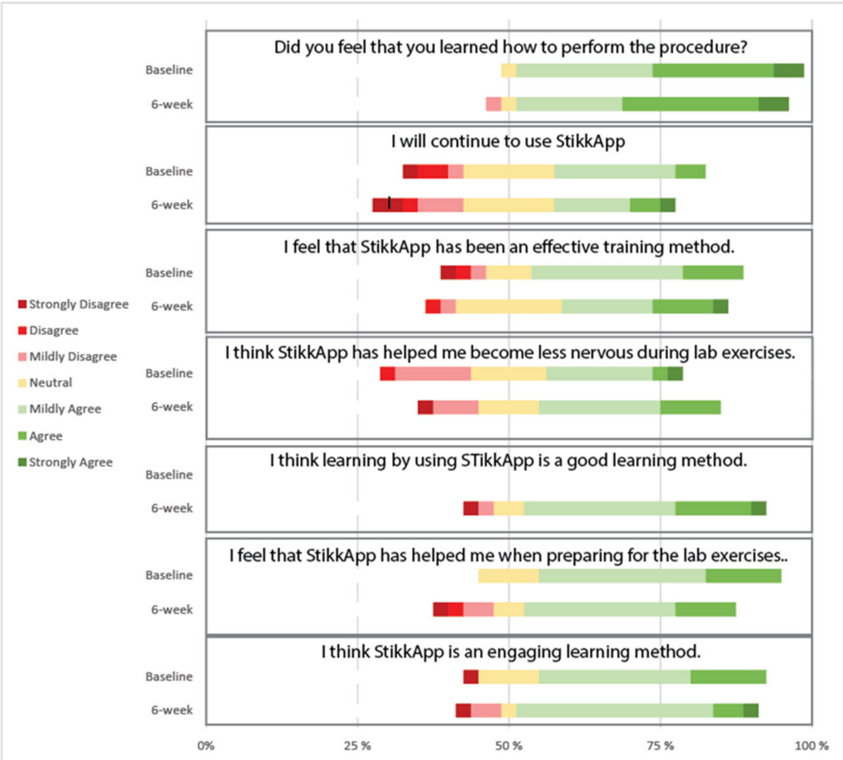

Figure 5. Results from two questionnaires administrated to the StikkApp user group (at baseline and/or after the 6-week period with phlebotomy training). Results are presented by a seven-point Likert scale by using color-coded divergent stacked bar charts.

Performing phlebotomy for the first time makes some students uncomfortable, nervous, or even fearful, and StikkApp was reported by some students to lessen the burden of nervousness (see Figure 5). Furthermore, students experienced the possibility of impacting the development of StikkApp and were motivated by it (see Figure 6A–C). Mirroring the prototype state of the StikkApp application, most students agreed that the application needs further improvement (see Figure 6D). The open textbox responses indicated that the users' main issue was that StikkApp was too repetitive. However, despite the prototype state of the StikkApp application, a large part of the students said that they wish to continue to use StikkApp (see Figure 5).

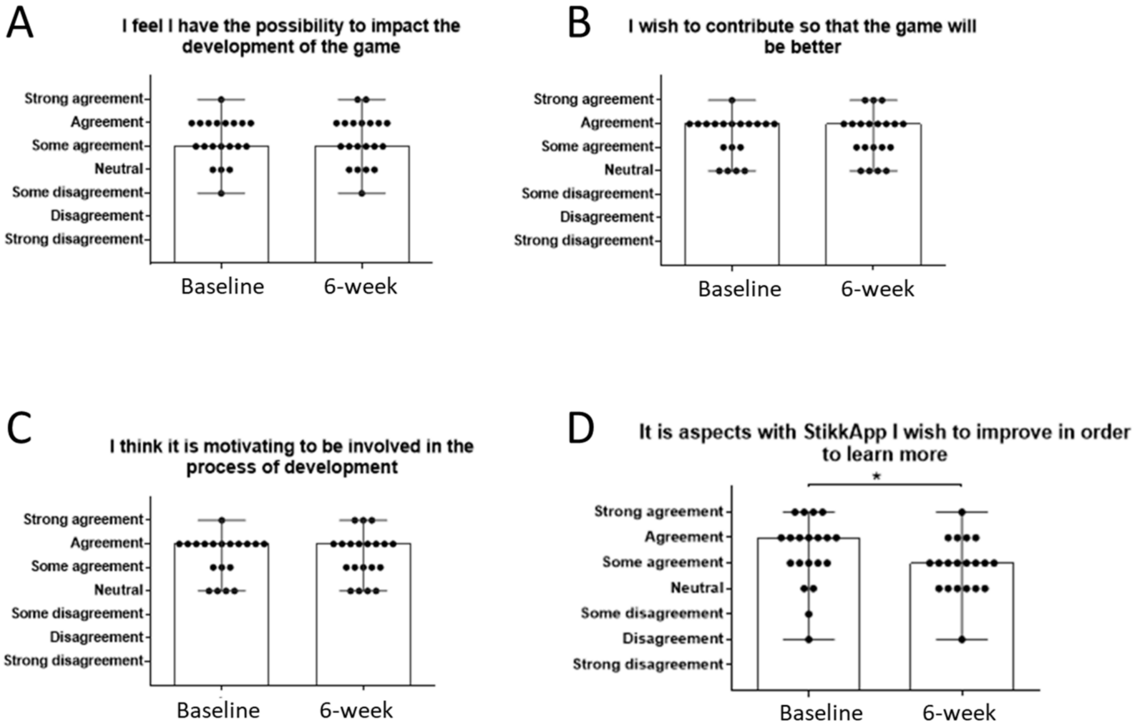

Figure 6. Results from questionnaires. Panel (**A**–**D**) presents results from two questionnaires administered to the StikkApp user group (at baseline and/or after the 6-week period with phlebotomy training). Results are presented by a bar chart (indicating median) overlaid with dot plot that shows individual data points and the whiskers indicating the minimum and maximum values of the data set. Abbreviations: * $p < 0.05$.

4.2. Summative Assessment Results

To obtain data on the potential impact of StikkApp use, one of the final exam questions was explicitly formulated to indicate the procedural knowledge: "6.a: Concisely describe the venous phlebotomy procedure.". A cohort comparison of the students' scores after the final exam was undertaken. Evaluating the median score of the two cohorts for the relevant sub-question, the StikkApp group obtained a score equal to the grade A (90–100% correct (median is 5 out of 5 possible)), while the median of the control group obtained a score equal to the grade B (80–90% correct (median is 4 out of 5 possible)). However, this small but statistically significant difference ($p = 0.02$) was only seen for the highly StikkApp harmonized sub-question. There is no statistically significant difference between the two cohorts when evaluating the other sub-questions or the total score of all the exam questions.

4.3. Interview Results

The results from the student focus interview have been categorized into four main categories:

- expectations to serious games,
- challenges of training phlebotomy skills,
- perception of serious games based on experiences in utilizing serious games for phlebotomy training, and
- suggestions and visions of using serious games in future learning.

These results also illustrate the students' views on the current challenges of BLS education, how teaching and learning methods can be improved and how games could further support such improvements.

4.3.1. Students' General Expectations of Serious Games

The students' primary expectation of serious games is that they provide opportunities for learning and further developing their practical skills. Serious games are also expected to be entertaining activities, which leads to motivation for learning. The motivating factor was considered particularly valuable when the course subject was considered difficult. For repeated training, the content should be varied between playthroughs. The difficulty level of the games should be adaptable based on the students' prerequisites, both on individual and educational levels. Ease of use was mentioned as a critical element. Learning by using serious games is expected to be easier to initiate than learning by reading books, particularly if the target platform is mobile or PC.

The primary game elements the students identified were rewards and scoring. Using games to provide different challenges to the same procedure was believed to have good potential. It was noted that it is essential to provide feedback regarding the players' performance to foster learning. While measuring student skills was mentioned as important, the application should not be too formal, i.e., every playing session should not be a part of the assessment of the students. The education already has many assessment situations; adding more should be done with care so as not to overload the students. Sometimes replacing other existing assessments was suggested as a way of allowing games to be used both for learning and assessment while keeping them fun and motivating.

An example mentioned of how a game previously used in their education was motivating is when they were told that Kahoot (a quiz-based multiplayer game [39]) would be used at the end of the lecture. While Kahoot has competitive elements, the interviewed students had mixed attitudes towards the use of competitions in serious games. Points, high scores, and competitions were considered to be potentially motivating, but these can also be a bit frightening and stressful. The participants said that some students are extremely motivated by using rewards, and also emphasized that there is not always a direct correlation between high scores in games and real-life skills. When Kahoot is used in the lecture, the students experience that they pay more attention in the lecture to perform well in the game session at the end. Limited scopes of competitions such as Kahoot are considered fun. One student said that she had been motivated to intensify her efforts by a classmate's having scored better than her.

4.3.2. Challenges for Learning Phlebotomy

A key barrier for the students when learning the phlebotomy procedure was the act of perforating the patients' skin and fear of the potential pain they could inflict. Additionally, there was so much new equipment that they struggled with gaining a good overview of what they had to do. A possible implication of the cognitive overload the students experienced is that at the initial stage the content should be split up into separate parts before they are faced with how everything fits together. With everything being new, they experienced that they "had no idea what they were doing". They also shared that remembering all the procedure steps and the correct order became difficult because of the stress. Details in the procedure, such as taking off the tourniquet, were forgotten because of the focus on venipuncture. The combination of stress and fear when they practiced the procedure also resulted in some of the students neglecting the intra-personal communication with the patient. Students experienced that it was hard to focus on the human interaction at the same time as they had to keep track of the rest of the elements of the procedure.

An additional challenge was handling the logistics of the procedure; where to place the equipment to use, which hand should be used for what, and where to position oneself. This could lead to difficulties when swapping blood tubes and reaching for new equipment. The importance of dexterity and finger skills for performing the phlebotomy procedure was also emphasized. Examples mentioned were information on how hard one needed to push the needle and the cannula, and the expected resistance. The participants wanted more opportunities to touch and feel veins and to be able to assess the best puncture point for each individual patient.

4.3.3. Students' Experiences and Perception for Testing StikkApp as a Learning Resource for Phlebotomy-Training

The students discussed aspects they were satisfied with regarding StikkApp. They experienced it as useful for learning the order of actions to be performed in the procedure and choosing the correct blood tubes in the proper order. In the beginning, StikkApp was particularly helpful for gaining familiarity with the equipment to be used. The possibility of repeated training of a procedure was highlighted as a good opportunity provided by serious games as well as the availability, compared to other learning tools. Based on their experience with StikkApp, the students think that a key effect that serious games have on their learning is increased motivation in learning situations. In this regard, the students mentioned serious games as an effective way to prepare for other traditional teaching methods, such as lectures and laboratory exercises.

When asked when the students think it is useful to play serious games in the learning process, they noted three primary aspects of procedural training: preparation, repeated training, and self-assessment. If games provide sufficient feedback, they will use them in preparation for skill-based training, before learning theory, as self-study opportunities, and as quick repetition. While they did not want the game to report constant scoring of their performance to the teacher, they believed that StikkApp and other similar games could be successfully used in evaluation settings of limited scope; for instance, by replacing the more theoretically focused assessments they currently must pass before participating in laboratory training.

Browser-based games such as StikkApp were considered most useful when starting to learn a new procedure, by visualizing the procedure and allowing the students to repeat the steps of it. They would also be useful as tools for quick repetition before exams. Games as learning tools during the period of the corona pandemic, with limited access to campus, were considered suitable for motivation, introducing variation from web-based lectures. This was especially apparent to the participants as they missed their clinical placements due to restrictions of the corona pandemic.

Another interview topic was how serious games correlate to other learning methods. A point mentioned here was how games let them gain a good overview of the procedure and material in the initial stages of learning, thus being a helpful tool to use before digging deeper into details of the theory. The positive effect of variation in learning methods accomplished by introducing serious games was emphasized. In contrast to most other learning tools, games provide interactivity that helps them in their learning, especially when interspersed with reading. Serious games are a valuable complementary learning tool, but the students especially emphasize the need to still have physical practice for procedures and laboratory work.

The students also gave feedback on how StikkApp could be improved from the version they played. A major aspect was the need for more variation to ensure they did not improve by learning the game itself but were continually tested on their factual knowledge.

The students particularly proclaimed a wish for more examples of patients with different requisitions and variations of veins, and a larger variety of situations with different degrees of induced stress, which is something they lack in their current education. They believe this would help prepare them for real-life blood sampling as they currently primarily train in "optimal" conditions. The students provided examples of situations that would be useful to experience: patients lying in bed, infants, enraged patients, frightful patients, etc. They have limited experience with some equipment because of cost, such as butterfly needles, which they would like to learn how to operate in a serious game.

4.3.4. Students' Suggestions and Visions of Serious Games in the Future

The students said that it could be valuable to use games in some limited assessment situations, for example, as a replacement for current assessments such as quizzes before laboratory sessions. It was stressed that while the games could be used in assessments, their primary use should be as engaging learning tools. They noted that other learning methods are still valuable and should not be replaced; they want games to be considered Supplemental Material.

When asked what they thought about competitive games integrated into the whole course, the students noted skepticism towards having competitions that lasted throughout the semester, instead preferring to have shorter and more informal ones as a fun factor. Splitting the course content into different subjects presented in a game so you could have a high score in each of those subjects was said to be interesting. This way, students could gain insight into their performance in the different topics. Some thought it was motivating to see how others were doing as well. Anonymous competitions were suggested as a potential approach. Different types of competitions should be considered in different situations as "people learn a little differently, and even if it is a really good app, there will always be someone who chooses not to use it as it is intended to be used".

An important aspect for the students is the constant availability of their learning tools, such as learning games. While immersive VR was mentioned as an engaging new opportunity, the availability of necessary equipment can vary. They were positive about games on mobile phones, as they could be used between other tasks, like relaxing on the couch or waiting for the bus.

Looking beyond the limitations of access to technical equipment, the students expressed interest in solutions providing high tactile feedback, realistic visual fidelity, and a high grade of presence. For example, using mannequin arms to practice venipuncture to gain better dexterity and a better finger feeling was mentioned as positive. The ability to feel the pressure was considered important. The students would also like to practice dexterity skills such as perforating the skin, filling blood tubes, and using touch to locate veins to attempt perforation on veins that are not possible to locate visually.

For more realistic visual fidelity, immersive VR was discussed as potentially complementing the experience of StikkApp and other serious games. The students provided the following examples which could be beneficial for their learning: more realistic depictions of veins, the possibility of testing out different placements of arms and various other equipment, practicing patient communication, and experiencing demanding situations. For this to be trained, immersive VR would be useful, mainly due to heightening the feeling of presence.

Without practicing interpersonal communications, the students do not feel ready to enter clinical practice. To this end, they believe that some aspects can be practiced through menu choices. Speech simulation is not necessarily required in every situation. Some demanding situations they wish to experience are handling children with various moods, scared patients, and fainting patients.

Adding sensors and haptic equipment was also potentially beneficial for training on skills requiring dexterity, such as feeling different types of veins, being aware of the angle they need to use when inserting the needle into the vein, and more. Adding these elements could also enhance the possibility of adequately experiencing the situation on an emotional level. Training for such experiences in a game was believed to be best in immersive VR with haptic, tactile devices.

Students consider self-confidence as a major barrier when performing phlebotomy. The ability to know what to do by having tried it out in a simulation beforehand, perforating the "skin", and filling blood tubes would prepare them for the "real life" situations.

All participants considered that getting to know the practice places before going there could help remove uncertainty when entering a real working place for the first time. Using an immersive VR version of the practice places could be helpful in getting to know the place, but videos might be good enough for this purpose.

Other aspects the students would like to practice through serious games were:

- Capillary blood sampling.
- Laboratory analysis of blood samples. Especially procedures that they do not get to train at school because of a lack of resources, such as butterfly kits for blood sampling.
- The structure of instruments.
- An app as a supplement to the lab booklet.
- Sources of error—what went wrong, and what were the consequences?
    - This would help to relieve the fear of destroying something when inexperienced.
    - Another help would be seeing the consequences beforehand, which might reduce nervousness.

4.4. Summary of Results

To summarize the main findings from describing this case study following Digital Game-Based Learning (DGBL) integration in the BLS Education:

(i) Most students perceived the DGBL application StikkApp to be an engaging and effective learning method for learning how to perform the phlebotomy procedure, and even—for some students—to reduce phlebotomy-related anxiety.
(ii) Students were motivated by experiencing the possibility of impacting the development of the DGBL.
(iii) The cohort comparison of the students' scores after the final exam for the question focusing on the procedural content indicated a small but statistically significant better efficacy for the StikkApp user group.

The in-depth insights and discussion of possible ideas for how DGBL can support health-care students were achieved through the focus group interview, elucidating four main categories:

(iv) *Students' expectations of serious games in learning the phlebotomy procedure:* It was acknowledged that serious games are expected to motivate and provide learning opportunities that are fun and engaging. This expectation is high, possibly because of earlier experiences with games. Variation, adjustable difficulty, ease of use, and feedback are important features. Serious games can be used for assessment as well, but it has been emphasized that it is important to strike a balance and ensure that the game is primarily used for fun and engaging learning.
(v) *Identified challenges of training phlebotomy skills:* Overall, a fear of hurting the patient and mental overload from the amount of new equipment can be important early obstacles for learning the procedure. These mental challenges resulted in procedural steps being missed and out of order, a lack of overview, and neglected communication with the patient. A current lack of tactile training opportunities was also emphasized.
(vi) *Different perceptions of serious games based on experiences utilizing StikkApp for phlebotomy training:* The game was beneficial for learning the order of actions and blood tubes to choose. In general, it helped us gain familiarity with the equipment, allowing frequent training on an available learning tool. Preparation, repeated training, and self-assessment were especially appreciated aspects. By using serious games, the students could more easily understand the procedures and have more variation and interactivity in their learning methods. However, they would like even more variation in learning scenarios providing examples of different patients and access to additional, difficult situations.
(vii) *Suggestions and visions of utilizing serious games in future students' learning:* The students believe that it is important to use serious games as learning tools for increasing engagement, but also that they could be used as assessment tools in a limited capacity. Shorter competitive sessions can engage the students. Ensuring the availability of the games is highly important. In that regard, targeting mobile phones would be good. Availability was a drawback of immersive VR, but interesting for practicing patient communication, trying out demanding situations, and real workplaces, as it allows

them to experience those situations more vividly. Serious games providing realistic tactile interaction were noted as compelling.

5. Discussion and Future Work

5.1. Game-Based Learning vs. Game-Based Teaching

This study shows that a distinction between game-based learning and game-based teaching is helpful. This distinction has been made by Skaug et al. [40], where game-based learning refers to the learning effect of the games in and of themselves. In contrast, game-based teaching refers to a wider teaching situation where the games are used as part of the overall teaching methodology. While the two concepts are interconnected, the activities supporting game-based learning are different from those who are supporting game-based teaching. The last is a necessary requirement if the aim is to introduce games in education and achieve game-based learning systematically. Suppose teachers would not support this study already at the design and development phase of the games [18], support students in how to use it, and discuss evaluation methods with the researchers behind this study. In that case, we believe the acceptance of StikkApp would have been lower. This should be a requirement for the successful implementation of serious games in education, especially for the initial introduction of a serious game in a non-computer science-related domain. Serious games should be primarily voluntary to facilitate learning, with the potential for limited assessment situations with compulsory participation. Irrespective of which approach is chosen, we highly recommend that teachers take an active role in implementation for ensuring the proper, successful integration of serious games. As an active learning tool, serious games open new possibilities for educators to engage the students. Game-based teaching can be highly valuable as a part of modern educational approaches such as blended learning or using games in flipped classrooms.

5.2. Serious Games for Reducing Nervousness

It is often challenging for students to perform phlebotomy early in the learning process. Some students reported StikkApp to lessen their burden of stress. This can be explained by several aspects. Research indicates that the implementation of technology for formative assessments can make students feel more at ease, contributing to better educational performance [41]. StikkApp users receive formative feedback to improve students' metacognitive skills about what they should do and make them aware of what they do not know, which might reduce their nervousness. This can be influenced by the current stage of the prototype, e.g., too little variation in the game's content, or the reduced level of immersiveness. Experiencing a sense of achievement, confidence and engagement in learning can also be a key factor for less nervousness [42,43]. Our results suggest that StikkApp users positively experienced the possibility that they could influence the further development of StikkApp.

5.3. Procedural Knowledge and Skill-Based Knowledge

The test group was found to perform slightly better than the control group when it came to procedural knowledge. However, these findings should be interpreted carefully due to the sample size. Learning situations are complex with impacting factors such as the room, situation, context, teacher, and follow-up. This means following only a single class may not be enough to draw conclusions.

A potential implication of this study is that technologies that support skill-based learning are different from those that support procedural learning. Students expressed the need for more immersive technologies combined with haptics and tactile feedback to learn the impact of feeling veins and skin, which are necessary for skills learning. Screens of laptops and mobiles were considered enough for learning processes. For constructing serious games supporting learning, it is beneficial to develop separate applications for learning skills and learning processes, even if these are different sides of the same coin.

Here, an example of current best support for aspects of the phlebotomy procedure is proposed:

6. *Training the venipuncture skill*. For these more immersive technologies, allowing dexterity training would be preferred.
7. *Learning the surrounding situation, such as correct order of actions, proper communication with the patient, choosing the correct blood tubes for the analysis to be made* etc. To achieve such knowledge and competencies, more accessible technologies would be enough, e.g., mobile phones or computer surfaces.
8. *Learning from context*. It would be beneficial to have another application for understanding how one and the same procedure and skills can be trained in different contexts. The students need to learn to take blood at schools, hospitals, or refugee camps [34]. They also need to take blood from different patients, and difficulties in such situations need to be trained for.

To have a solution that allows students to train these parts in conjunction is currently lacking. In the case of serious games, it is an open question whether the best solution is to have an all-encompassing game including both parts and to have them separated. An additional alternative is to have individual games or sub-games that allow the students to mass-practice the parts separately and can utilize other devices, for example, in VR or AR.

5.4. Learning Context

A potentially important aspect of learning phlebotomy and other procedures is the learning context. How one defines the context might be essential; is it the process from greeting the patient until sending the samples for analysis, is it the surrounding environment and/or something else? Are all these contextual facets important, and what are the impacts of including or excluding them?

The students wanted to get to know their practice places before going there and were interested in using immersive VR solutions and videos to achieve this. A prototype immersive VR game has had initial testing where students played through learning scenarios where they performed the phlebotomy procedure in authentic environments [34]. The potential of such a solution should be further explored.

5.5. Methodological Considerations

The successful introduction of serious games in BLS education is a complex issue with many influencing aspects and possible (non-exclusive) outcomes. It is a difficult task to distinguish the separate impact of teachers, students, and the design of the game, on varied outcomes such as motivation, engagement, and performance in one and the same study. Therefore, mixed methods [44] were chosen. By utilizing both qualitative and quantitative methods, a broad range of data has been gathered and analyzed.

The choice of having a longitudinal study likely impacted the resulting data. The group interview was performed after the semester and allowed for unique discussions regarding how students remembered the study after an even longer time.

While the choice of methodology provided unique insights into the issue at hand, it also provided some challenges. The resulting amount of data and information can be unwieldy and difficult to ensure a comprehensive analysis of. Additionally, a case beginning with participatory design traditions [18], and following a longitudinal, interventional cohort study, results in trade-offs regarding the ease of reproducibility. A separate issue was caused by the pandemic, causing parts of the study design to have to be altered partway through. A final laboratory observation had to be canceled, where the goal was to provide data on the performance after the physical phlebotomy procedure.

As one of the perceived benefits of serious games is fun and engagement, the study was designed such that the difference between the target group and the control group was their access to the game. Whether or not the students used the game was their own choice, as being forced to use it could negatively impact their experience. Additionally, this ensured a more realistic scenario for the case study, providing insights that would likely not be possible if students were forced to play.

5.6. Future Work

This case study could help serve as a basis for future studies into frameworks for successfully integrating serious games into BLS education. Aspects that would be useful to this end might include the design and development of serious games using participatory design, teacher involvement for game-based teaching, utilizing additional technologies, and extending the program with contextual training. Several of these issues were discussed earlier. To examine these new aspects and technology usage, a better understanding of implementation is necessary. Based on the aspects enumerated in Section 4.4 (i–vii), we plan to develop a framework for harmonizing technology design and development to the implementation of games in the educational domain by considering contextual requirements.

With promising results from using immersive VR in other medical procedures, such as surgery training [45] and laboratory training [46], the technology should be further assessed also for phlebotomy training. To the authors' knowledge, no studies measuring the performance impact of immersive VR on students' phlebotomy skills have yet been conducted. While there are development projects such as VIDA- Nursing V1.0 [35] and 360-Phlebotomy [34], their performance impact has not yet been measured. Thus, further research into the possibilities of immersive VR training for phlebotomy is suggested.

For future studies, it should also be interesting to investigate further the effect of voluntary vs. forced use of serious games. While this study can provide some indications, it is unclear exactly how to best balance these approaches to achieve the best possible positive effect on BLS education and other related educations.

6. Conclusions

The goal of this paper is to provide insight into how Digital Game-Based Learning (DGBL) can support health care studies in learning the phlebotomy procedure, with a particular focus on procedural knowledge. To achieve this, a serious game for the phlebotomy procedure was tested with a class of first-year students at the biomedical laboratory science (BLS) education over 5 months.

In conjunction with physical phlebotomy exercises, the students filled out questionnaires on various self-assessment topics related to learning methods, with a particular focus on the use of DGBL. The questionnaire results revealed, among other things, that (i) a majority of the students believe that DGBL is a good learning strategy and some students also reported that StikkApp had helped to lessen the burden of nervousness, and that (ii) the possibility of impacting the development of the game was motivating for the students.

The summative exam of the course included a question aimed at measuring procedural knowledge, which showed (iii) a statistically significant difference in the exam scores. The target group using the game scored somewhat higher and responded more accurately to questions related to understanding the phlebotomy process than the control group.

Students participated in a focus group interview, contributing to increased understanding of using serious games, which related to four main categories regarding their current: (iv) expectations for serious games, (v) opinions for challenges of training phlebotomy skills, (vi) perception of serious games based on experiences on utilizing these for phlebotomy training and (vii) suggestions and visions of using DGBLs in future.

The results from this study can serve as background for a variety of future studies, e.g., exploring specific frameworks, which is an important next step in providing actionable advice for how to integrate DGBL in BLS education, and informing other cases for utilizing mixed methods to evaluate the implementation of DGBL in education. Moreover, the results of the paper indicate that Virtual Reality and cooperative games should be further explored for use in BLS education.

7. Patents

We have submitted a disclosure of invention and, for this reason, cannot share the source code of the application.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/computers11050059/s1, Document S1: Interview guide.

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