RESEARCH ARTICLE

The effect of an e-learning module on health sciences students′ venipuncture skill development

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TJ Lindenmaier, J Brown, L Ranieri, D Steary, H Harrison, J Flook, E Lorusso. The effect of an e-learning module on health sciences students' venipuncture skill development. Can J Respir Ther 2018;54(1):1–5. doi: 10.29390/cjrt-2018-002.

Introduction: Venipuncture is a psychomotor skill required in many healthcare professions. E-learning could be used to overcome current barriers in face-to-face learning in healthcare education such as insufficient classroom space or qualified instructors. We sought to evaluate the effectiveness of an e-learning module on students' performance when used in addition to in-class training.

Methods: Overall, 224 health sciences students were approached to participate in this pilot study. Recruited students were divided into control and study groups. The control group received only in-class training, whereas the study group had access to the e-learning module in addition to in-class learning. Both groups were evaluated on their self-confidence using a Likert scale, academic competence using a multiple-choice questionnaire, and psychomotor competence from video skill recordings using an in-house rubric. Nonparametric, independent sample Mann-Whitney tests were performed to evaluate differences between groups.

Results: Overall, 114 students provided written informed consent; 84 students (control: $n = 50$, study: $n = 34$) participated in at least one component of the study. Significantly higher ($p = 0.017$) academic competence scores were observed in the study group. Significantly higher confidence levels were also observed postintervention for both the control ($p = 0.0025$) and study ($p = 0.0011$) groups; however, no significant differences were found between the study and control groups before ($p = 0.441$) or after ($p = 0.883$) intervention. Finally, no significant differences ($p = 0.428$) were observed for psychomotor skills between the study arms.

Conclusion: Our results suggest that there is potential for e-learning to increase the academic competence of students when used in conjunction with traditional learning; however, further research is needed to determine its efficacy on psychomotor skills.

Key Words: *e-learning; venipuncture; psychomotor skill*

INTRODUCTION

Psychomotor skills are essential in many healthcare professions. In the past, these skills have been taught, reinforced, and evaluated to the new generation of health care workers through in-class labs and simulations with a face-to-face instructor. With emerging technology, e-learning and other forms of computer-assisted learning have become a critical part of education in general and have been implemented for healthcare professions [1–3]. There is very limited research exploring the effectiveness of e-learning on the acquisition of psychomotor skills in health sciences, a key component in the field [4, 5]. Major limitations of face-to-face learning include limited classroom space and an insufficiency of qualified instructors in settings where there are high demands for healthcare education [6]. For students in clinical learning settings, additional barriers include a lack of procedural knowledge among institution staff and preceptors, costs of training equipment, and low patient need for certain procedures resulting in insufficient learning opportunities for students [7]. We postulated that e-learning would be a useful tool in overcoming these obstacles. Thus, it is worth further exploring the effectiveness of online education on student learning when used in addition to traditional classroom-based settings. Online material could enhance face-to-face learning by acting as a supplementary tool for students' learning. It also has the benefit of allowing students to pause or repeat aspects of procedural learning should they not understand them initially. Furthermore, a major limitation of learning procedural skills in the classroom setting alone is the inability to practice these skills outside of the classroom. Students may learn a procedure such as venipuncture in the classroom, but without the opportunity to regularly practice and refresh their knowledge these skills may be lost before students are able to use them in clinical placements or the workplace. While students can review the procedures they have learned in the classroom, reading alone will not allow students to retain certain technical aspects of procedural skills. Videos demonstrating these procedures, such as the videos in our e-learning module, may reinforce these more technical aspects of the procedure.

The task of performing venipuncture, an essential psychomotor skill in many healthcare professions, requires academic competence, confidence, and proper dexterity for successful performance. Our goal was to determine whether an e-module on performing venipuncture (developed in-house) would be beneficial for students' performance. In particular, we sought to determine if e-learning in conjunction with in-class training would (*i*) increase students' confidence, (*ii*) increase students' academic competence, and (*iii*) improve students' psychomotor skills. A study by Worm et al. [8] showed that the use of video and simple animations in online learning improved students' performance compared with the use of only text, images, audio, and simple interactivities for content presentation. Our e-module fits the description of the former type of learning, and when used in conjunction with in-class learning, we would therefore expect students to benefit from the e-module. Thus we hypothesise that students will perform better in all three areas of evaluation when e-learning is used in addition to in-class training.

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METHODS

Study participants

All study participants provided written informed consent to partake in this pilot study. The study protocol was approved by the community college Research Ethics Board (#16-05-02-1). Study participants were students recruited from Health Science Programs at a community college in Southwestern Ontario. Study representatives approached students during the fall semester with a short presentation explaining the study. Study representatives emphasized that the study was an optional component of students' education, that participation or lack thereof would have no effect on students' evaluation, and that the e-module would be made available to everyone upon completion of the study, whether they participated or not. Furthermore, while instructors from several of the programs were involved in the studies, they did not approach students within their own classes. With the exception of skills gained from participating in the e-learning module, there was no added benefit for students participating in the study. In total, 224 students were approached: 64 from paramedicine, 87 from practical nursing, 62 from respiratory therapy, and 11 from magnetic resonance imaging. All students from paramedicine, practical nursing, and respiratory therapy had recently started their second year of study while the post-graduate magnetic resonance imaging students were in their first year of study.

E-learning module

Paper-based text material developed by London Health Sciences Centre was converted into a self-paced, visually rich, interactive module designed with Richard Mayer's Multimedia Principles in mind [9]. For example, care was taken to delete extraneous material (Coherence principle), cue students to key ideas (Signaling principle), and break content down into manageable chunks (Segmenting Principle). The e-learning module consisted of six main sections: Venipuncture Site, Equipment, Preparation, Procedure, Complications, and Continuing Care. Forward and back buttons were included for linear progression through the content, as well as a navigation menu outlining the main and sub-sections of the material to allow for more specific content retrieval. Checkmarks next to menu sections served as a visual marker of progress through the module and allowed students to identify which sections were previously completed. Various interactive activities throughout the module were designed to reinforce learning through retrieval practice. Retrieval practice has been shown to be one of the most powerful methods of learning [10]. Videos throughout the module provided a visual demonstration of psychomotor skills. Cooper et al. [4] reinforced the growing body of research showing the effectiveness of online instructional videos in demonstrating psychomotor skills. Each section began with a reflection task designed to prime students' curiosity for deeper cognitive processing. Curiosity has been shown to reliably encourage student engagement [11].

Data collection

Recruited students were randomly divided into two groups, a control group and a study group, using an online random number generator [12]. The control group was educated using traditional in-class training, consisting of readings, lectures, and lab demonstrations. In contrast, the study group had access to our e-learning module through the learning management system used for teacher–student communication and sharing of course material, in addition to traditional in-class training. Students in the study group had access to the module throughout the entire semester, whereas students in the control group received access to the module after study evaluation was completed but prior to their final exams. This ensured that students from the study group did not have additional benefits in their academic education.

Participants were assessed on three separate competencies all completed during the fall semester of 2016 to coincide with scheduled in-class learning of venipuncture skills in all programs. Students' self-confidence was recorded before and after intervention. Both control and study groups' confidence levels were evaluated using a Likert scale (administered through the college's online learning management system) that is similar to the scale developed by Hicks et al. [13]. A sample questionnaire is shown in Appendix A. Academic competence was also evaluated postintervention using a short assessment, which was administered through the college's online learning management system and which consisted of 13 multiple-choice questions on performing venipuncture (see Appendix B). Finally, to evaluate psychomotor skills, students were video recorded while performing venipuncture on mannequin arms (Life/Form Adult Venipuncture and Injection Training Arm LF00698U) at an anatomical site (antecubital fossa or hand) most convenient to them [14]. Students' identities were hidden in the videos by focusing the camera only on the students' hands and the surface on which venipuncture was being performed. The students' faces, names, and audio were not included in the recording. Several instructors then graded students by viewing the video recordings. To avoid bias and potential recognition of student identity, instructors only graded students who were not enrolled in their courses. To measure psychomotor competence, a rubric (see Appendix C) similar to the one previously tested and utilized by the respiratory therapy program was employed.

Data analysis

The score for psychomotor competence was calculated by averaging the total score given by two instructors. Nonparametric, independent sample Mann-Whitney tests were performed using GraphPad Prism (V7.00 for Windows, GraphPad Software, La Jolla California USA) to evaluate differences between control and study groups for psychomotor skill, academic competence, and confidence pre- and postintervention.

RESULTS

A total of 114 candidates provided written informed consent to participate in the study leading to a 51% response rate. Overall 84 students completed at least one component of the study. Of these, 50 participants were from the control group: 18 paramedicine, 14 practical nursing, 16 respiratory therapy, and 2 magnetic resonance imaging students. Furthermore, there were a total of 34 participants in the study group: 8 paramedicine, 13 practical nursing, 12 respiratory therapy, and 1 magnetic resonance imaging students. Due to the low response rate, students from the separate health science programs were grouped together within the control and study groups for analyses. Figure 1 displays a detailed breakdown of the two study arms with a summary of the number of students in each group and components completed.

As shown in Table 1, there were no significant differences observed between the control and study groups for pre- or postconfidence level scores. Additionally, as shown in Table 2, significantly higher postconfidence level scores were observed for both the study ($p = 0.0011$) and the control ($p = 0.0025$) groups than preconfidence level scores. Interestingly, as shown in Table 1, students in the study group scored significantly higher ($p = 0.017$) on their multiple-choice test, which was designed to assess students' academic competence. Finally, as shown in Table 1, there were no significant differences observed between the study and control group scores when testing psychomotor skills.

DISCUSSION

Our goal in this study was to determine whether an e-learning module, when provided in addition to traditional in-class training, would improve health sciences students' confidence, academic competence, and psychomotor skills. We hypothesised that students will perform better in all three components of the study when e-learning is used in addition to in-class training. Our results suggest that there was no significant difference in confidence levels for students in the control and study groups pre- or postintervention. We observed an increase in confidence for both groups by the end of the intervention. This was expected, as both groups received in-class instruction. Additionally, students in the study group scored higher on their academic evaluation than the students in the control group, which suggests that e-learning or other forms of computer-assisted learning have the potential to improve academic competence when used in conjunction with traditional techniques.

Unexpectedly, we found that students who had access to the e-module did not improve their psychomotor skills more than students who only received in-class training. This finding may suggest that

FIGURE 1.

Study arms. A detailed breakdown of the total number of students in each study arm. The total number of students approached and those who did not participate are also outlined.

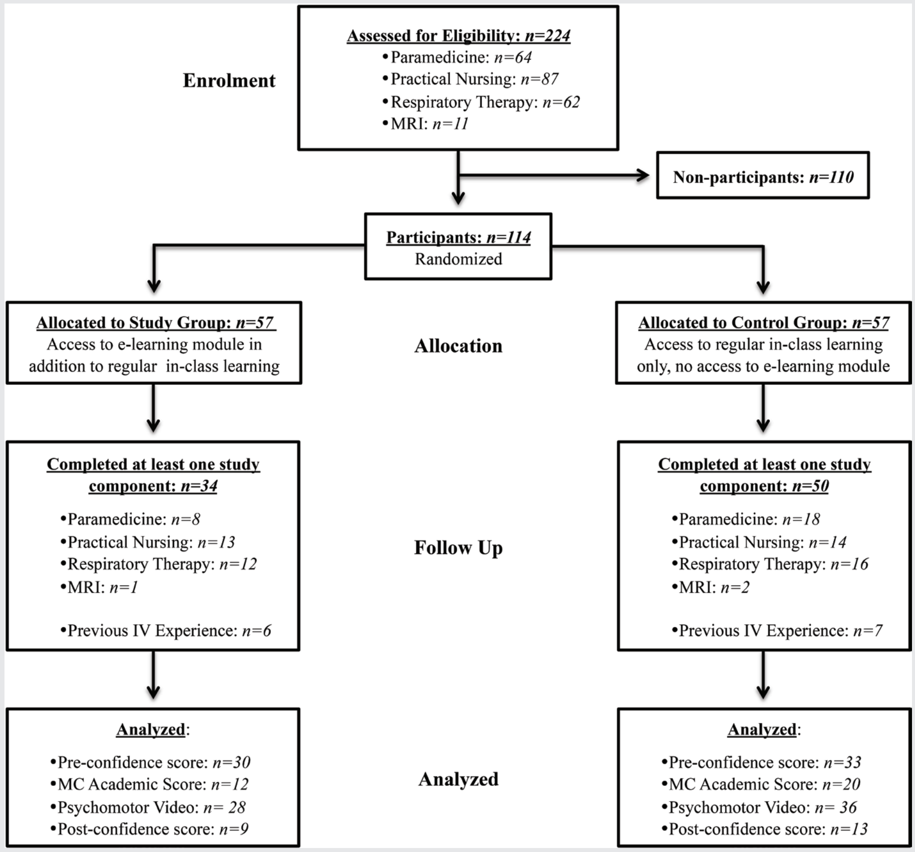

TABLE 1

Differences between control and study groups

	Control group *N*, mean (SD)	Study group *N*, mean (SD)	*p*
Preconfidence score	33, 50.1 (13.6)	30, 47.1 (16.4)	0.441
Postconfidence score	13, 61.8 (8.5)	9, 63.1 (5.0)	0.883
Multiple choice academic score	20, 10.1 (1.8)	12, 11.6 (1.6)	0.017
Video-based psychomotor skills	36, 17 (3.4)	28, 17 (3.0)	0.428

Note: N, number of data points.

TABLE 2

Differences in pre- and postconfidence scores for control and study groups

	Preconfidence score *N*, mean (SD)	Postconfidence score *N*, mean (SD)	*p*
Student control group	33, 50.1 (13.6)	13, 61.8 (8.5)	0.0025
Student study group	30, 47.1 (16.4)	9, 63.1 (5.0)	0.0011

Note: N, number of data points.

psychomotor skills are difficult to transfer through e-learning; however, this needs further validation, and e-learning should not be dismissed as a possible means of transferring psychomotor skills. Work is currently being done to understand optimal methodology and e-learning module setups. A meta-analysis conducted by Gugenfurtner et al. [15] identified user control of the level of difficulty as well as student assessment after training (rather than during training) to be effective strategies for improving students' self-efficacy and transfer of learning. Future online modules for intravenous training may be more effective if they were in the form of interactive digital simulations as opposed to or in addition to videos demonstrating the skill. User control of difficulty level should be incorporated into the design of future intravenous training modules. As technology continues to progress, novel and more interactive e-modules could be developed which could prove to be more successful in cultivating psychomotor skills. Current work suggests that e-learning modules need to be used in conjunction with face-to-face learning with a focus on enhancing both teaching and learning [16].

Several limitations of our study should be addressed. Because of the low response rate of students, our sample size was relatively small. Furthermore, of the students who did participate, not all completed each of the three assessments (academic, psychomotor, and confidence). This issue limited the types of analyses that could be performed. A larger sample size would have allowed us to look at differences within health sciences programs, as there are differences in the level of in-class instruction that students receive in each program and these differences should be accounted for. To increase the student response rate for future studies, a more controlled intervention should be planned. While the e-module, the confidence assessment, and the academic evaluation were easily accessible for students, there was no true incentive for students to complete all components, and there was no way to actually confirm that students in the study group had truly completed the module, rather than simply accessing the module's link without reviewing the content. Thus a study could be designed where the module usage is monitored and better controlled.

Not all students chose the same anatomical site for performing venipuncture. While this is a limitation, we do not believe that this was a major contributor to our results. The e-module mainly focuses on venipuncture at the antecubital fossa and students were instructed to find any appropriate site during their psychomotor skill testing. Thus, most students found it appropriate to perform venipuncture in the hand, which is a skill taught during in-class instruction in some of the health science programs. While we believe that there is sufficient overlap in the skills required to perform venipuncture at these two anatomical sites, future studies should be site-specific to reduce the chance of variation in measurements.

Future studies should effectively incorporate an e-learning module into students' training. This would increase the likelihood of module and assessment completion, increase sample sizes, and possibly yield a more well-controlled study. Time commitment and attention span required may both play a role in the completion of all components of the study. Thus the length of the e-learning module should also be taken into consideration [17]. Future studies should also focus on a single objective to decrease the time commitment of students, which may further increase the response rate. Finally, future work could explore the impact of this e-learning module on students who are already in the clinical component of their education, as it would be more relevant to them at that time of training and could boost the response rate.

CONCLUSION

Our results suggest that there is potential for an e-learning module to increase the academic competence of students when used in conjunction with traditional learning; however, further research is needed to determine its efficacy on psychomotor skills. With emerging technology and new advances in the field, more well-controlled experimentation is needed to determine the importance of e-modules and other computer-assisted learning tools in aiding in the development of psychomotor skills in the health sciences learning environment.

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APPENDIX

Appendix A. IV Insertion Self-Confidence Scale

Insertion skill	Not at all confident	Somewhat not confident	Somewhat confident	Moderately confident	Very confident
Preparation					
How confident are you that you can:					
1. Ensure the patient has provided informed consent	1	2	3	4	5
2. Explain the steps to be taken to the patient	1	2	3	4	5
3. Choose an appropriate vein	1	2	3	4	5
4. Choose the appropriate equipment and PPE	1	2	3	4	5
Insertion					
How confident are you that you can:					
5. Effectively apply the tourniquet	1	2	3	4	5
6. Safely prepare the site, following institutional policy	1	2	3	4	5
7. Anchor the vein and insert catheter at the appropriate angle	1	2	3	4	5
8. Verify entry of catheter into the vein	1	2	3	4	5
9. Attach the IV fluid line to the catheter	1	2	3	4	5
10. Safely secure the insertion site and stabilize the tubing	1	2	3	4	5
Follow-up					
How confident are you that you can:					
11. Document your initiation of IV	1	2	3	4	5
12. Evaluate the effectiveness of your initiation of IV insertion and troubleshoot any problems?	1	2	3	4	5
13. Quickly and accurately access an IV insertion on a mannequin	1	2	3	4	5
14. Teach someone to perform this skill?	1	2	3	4	5

Source: Adapted from Hicks et al. [13].

Appendix B. IV Test Questions

1. Which of the following IV cannula gauge sizes is appropriate for a patient 80 years of age who needs IV access for pain management?
   a. 24 gauge
   b. 22 gauge
   c. 18 gauge
   d. 16 gauge
2. Which of the following is the best choice when selecting the size of IV cannula?
   a. The largest one you feel you can successfully insert in the patient
   b. The smallest one you can find
   c. The smallest gauge to accommodate the purpose
   d. The largest gauge your facility has
3. When a patient who needs an IV has cold extremities and few veins are visible or small, which of the following are acceptable techniques to help improve the likelihood of a successful IV insertion?
   a. Turn up the heat in the room and return in about an hour when the patient is warmer
   b. Apply warm packs to the extremity for 5-10 minutes
   c. Blow warm air on the extremity with a blow dryer for 3-5 minutes
   d. Allow the tourniquet to remain in place for a few minutes while you prepare your equipment
4. If a patient is expected to need multiple IV's or an extended hospitalization, it is best to choose which of the following sites for the first IV:
   a. Antecubital fossa
   b. Non-dominant hand
   c. Dominant forearm
   d. It doesn't matter where the first IV is placed
5. When assessing vessels for venipuncture, why should a vessel NOT be used if it is pulsing?
   a. A pulse indicates the vessel it is an artery
   b. A pulse indicates the patient is hypertensive
   c. A pulse indicates the patient is hypotensive
   d. A pulse indicates the patient has a fistula
6. While in the process of inserting an IV. Which of the following may result in a complication?
   a. Entering the skin at a 15-45 degree angle
   b. Reusing the device as long as it is in the same site as the original attempt
   c. Entering the skin directly over the vein
   d. Entering the skin slightly adjacent to the vein and directing the needle into the side of the vein wall
7. After applying the tourniquet, if the vein feels hard or rope-like, you should:
   a. Use it, it's the best choice for an IV
   b. Stretch it to prevent rolling
   c. Select another site
   d. Have the patient relax his/her fist
8. How can you verify that you have entered the vein with the IV catheter?
   a. You will be able to see the catheter through the skin
   b. You learn through experience where the vein should be located
   c. You observe a flashback of blood
   d. You palpate with your non-dominant hand for the "pop of the vein when the needle enters it
9. Prior to insertion, holding the skin taut below the chosen vein will help with:
   a. Interrupting the blood flow to the heart
   b. Preventing movement of the vein as the catheter is inserted
   c. Minimizing vein collapse as the catheter is inserted
   d. Preventing contamination of the cleansed site with your non dominant hand
10. What step would you take if you have attempted IV access and are unsure of proper placement?
    a. Remove the catheter and try again
    b. Attempt to flush the catheter
    c. Pull the catheter back a few millimeters and check for blood return
    d. Go ahead and begin IV infusion
11. When discontinuing the IV which of the following will decrease the formation of a bruise at the site?
    a. Apply direct pressure over the site as soon as the needles exits the skin
    b. Massage the area just above the site to encourage clot formation
    c. Apply a cold compress to enhance venous constriction
    d. Apply pressure above and below the site for two minutes after the needle is removed
12. What would be an indication that your IV insertion attempt was not successful? Select all that apply.
    a. The insertion site begins to bruise
    b. The insertion site does not flush easily
    c. The site swells when fluids are flushed through
    d. The patient complains of a cold sensation
13. After 2 unsuccessful attempts at insertion of an IV, the best thing for a health care professional to do would be:
    a. Call the physician to tell them you can't get the IV
    b. Keep trying until you get the IV
    c. Consult another professional to attempt the IV if available
    d. Hydrate the patient with oral fluids and try again in a few hours

Appendix C. Intravenous placement (peripheral)

Attempt	Score (0, 1, or 2)
Wash hands/PPE	
Select an appropriate vessel	
Prepare all equipment	
Effectively apply the tourniquet	
Prepare site for intravenous placement	
Perform cannulation	
Remove tourniquet	
Assess patency of the system	
Secure catheter and tubing to skin	
Attach IV fluid line to catheter	
Safely dispose of sharps	
Clean up area	
Patient safety jeopardized	
Total Score	
Score each:	
2 Points: Completed satisfactorily	
1 Point: Completed with difficulty	
0 Points: not acceptable	
N/A: Task not applicable to the patient-care situation	