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Evaluation of a Novel 3D-Printed Task Trainer for the Simulation of Gynecological Procedures at a Medical Academic Center

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Abstract

Introduction

Learning and mastering the performance of gynecological procedures in a secure and supervised simulation setting is important for learners, especially in the early phases of medical education. This project aims to assess the efficacy of an innovative gynecological task trainer for diverse simulation sessions. Following engagement with the task trainer, learners evaluated their experiences with a comprehensive questionnaire. The results of the survey were scientifically analyzed and interpreted.

Methods

The innovative gynecological task trainer was created with 3D-printed plastic, silicone, and a tabletop base. Learners engaged in simulations in which they performed gynecologic procedures using the task trainer. Subsequently, they provided evaluations and feedback through an online questionnaire that utilized a 5-point Likert scale to evaluate the task trainer.

Results

One hundred seventy-seven learners participated in simulation sessions utilizing the gynecological task trainer. Of these,132 learners completed the online questionnaire. The survey responses indicated that the task trainer was most suitable for beginner-level trainees. The majority agreed that the simulation was realistic, provided practice with medical instruments, enhanced their learning, increased their comfort with performing the procedures, and provided an opportunity for successful procedure completion.

Conclusion

The low-cost, novel 3D-printed gynecological task trainer can be easily assembled with basic hardware supplies, a 2-part silicone mixture, and access to a 3D printer. The tabletop trainer is

well suited for group simulations and offers learners a realistic simulation setting for practicing gynecologic procedures in a secure, supervised, safe learning environment. Overall, learners agreed that the task trainer enhanced their simulation sessions.

Introduction

Medical simulation is crucial in educating and training medical students and resident physicians. Learning to perform gynecological procedures with a low-cost three-dimensional (3D) printed task trainer provides realistic and deliberate practice. It offers a safe and effective way to develop clinical skills, improve decision-making, and prepare health care professionals to deliver high-quality patient care [(1, 2)]. High-fidelity and costly obstetrical simulation models have been widely used for teaching, training, safety, quality, and medical certification[(3)]. However, few low-cost yet realistic simulation models for gynecologic procedures exist. Due to the extensive medical knowledge and skills required in medical education, it is crucial to incorporate simulation training, particularly for fourth-year medical students and first-year resident physicians, to better prepare them for performing procedures on live patients[(4)].

The most helpful simulation models are economical and realistic, allowing them to be efficiently utilized in various learning opportunities[(3)]. For these reasons, lower cost and improved simulation models are frequently sought. Simulation sessions have involved learners participating in gynecologic procedures using fruit, such as papaya, to represent the uterus[(5)]. However, in our experience, using fruit was not anatomically realistic or conducive to performing gynecologic procedures. Subsequent simulation ideas were described by Hellier et al., in which a polyvinyl chloride (PVC) tabletop model with a racquetball simulating the uterus was described[(2)]. With this model, the PVC apparatus represented the vagina. The learners could insert a speculum and visualize the simulated uterus. Although this PVC model was significantly better than using papaya as a uterus, a model with a more realistic cervix and durable, reusable parts was envisioned as the next step in advancing education with gynecologic simulation.

Recent simulation evolution outside medical education has included digital simulator design and three-dimensional (3D) printing. Thus, it logically followed that the next step in advancing gynecologic simulation would involve similar technology. Digital simulator design is a manufacturing process in which three-dimensional solid objects are created from a digital file.

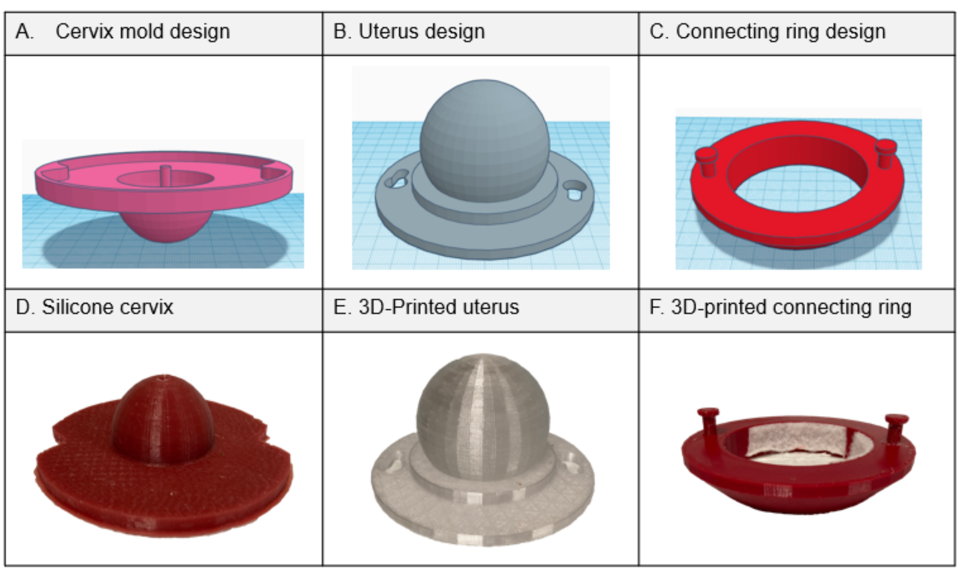
This allows complex shapes to be made from small amounts of material in an economical and fast process[6]. 3D printing is already used in many industries, including automotive, aviation, construction, and consumer products, like eyewear, jewelry, and footwear. Recently, 3D printing has found its way into the healthcare industry, offering diverse applications and advantages. One notable application is its role in enhancing medical simulation education[7].

We have created a new gynecological task trainer with 3D-printed components. Before implementing this research, the task trainer was used for gynecological procedure simulations with obstetrics and gynecology medical students. Informal verbal feedback was sought from instructors and learners as to the design, usability, and overall evaluation of the task trainer. The initial feedback was positive, so a formal evaluation of the task trainer was initiated.

Methods

Using the free Tinkercad 3D design program, we designed a uterus, cervix mold, and connecting ring (Figure 1).

Figure 1: 3D-Printed Plastic and Silicone Components
The cervix mold (A), uterus (B), and connecting ring (C) were created using 3D design software. The cervix was created by pouring a dyed silicone mixture into the cervix mold (D), and the uterus (E) and connecting ring (F) were printed with a 3D printer.



The staff in the university's maker studio printed the components with a 3D printer. The cervix mold was used to create an average-sized and realistic silicone cervix model. The average human cervix measures 2.5 cm in length and 2.5 cm in width[8], and the silicone cervix we designed has dimensions of 3 cm in length and 3.8 cm in width. The average size of an adult female nongravid uterus is 8 cm[9], the same length as the 3D-printed uterus with the cervix in place. The cervix is held in place between the uterus and a connecting ring that interlocks. The pieces are thus quickly assembled. The task trainer consists of a wooden base, PVC tubing, and a PVC sanitary "T" connector piece, as described initially by Hellier et al.[2]. The novel uterus and cervix are then affixed to the sanitary "T" piece with hook-and-loop tape (Figure 2). A gel can be placed inside the uterus to simulate tissue; the gel can be obtained and extracted during endometrial biopsy and manual vacuum aspiration procedures. The translucency of the uterus allows learners to visualize instruments when passed through the cervix and into the uterus. The task trainer is low-cost at approximately $15.38 per model (Table 1).

Institutional review board approval was obtained to begin implementing this quality improvement project. A mixed methods approach was utilized, including quantitative data collection via survey questions and qualitative capture of feedback using open-ended survey questions and verbal feedback collected during simulation sessions. The study population included students, resident physicians, and clinicians at one medical center. Most learners were in the OB-GYN specialty. The learners participated in simulations where they performed gynecological procedures utilizing the task trainers, including Pap smear collection, cervical polyp removal, uterine sounding, endometrial biopsy, insertion and removal of intrauterine device, cervical dilation, and manual vacuum aspiration. After each simulation session, the learners were asked to complete the survey questionnaire.

Survey questions were based on the instrument described by Abdo and Ravert[10]. Additional questions were added to capture responses deemed necessary for the learners to evaluate this specific task trainer adequately (Table 2). A 5-point Likert scale (5-strongly agree, 4-agree, 3-neutral, 2-disagree, and 1-strongly disagree) was utilized for quantitative measurement to standardize responses, reduce response bias, and enhance the data's reliability. The survey had two demographic questions: a question about what education level the task trainer would be most appropriate for, six task trainer evaluation questions, and two qualitative feedback questions for comments. There were three additional questions for those who completed the manual vacuum aspiration simulation sessions. The data was analyzed, and measures of central tendency are used to describe the survey findings.

Results

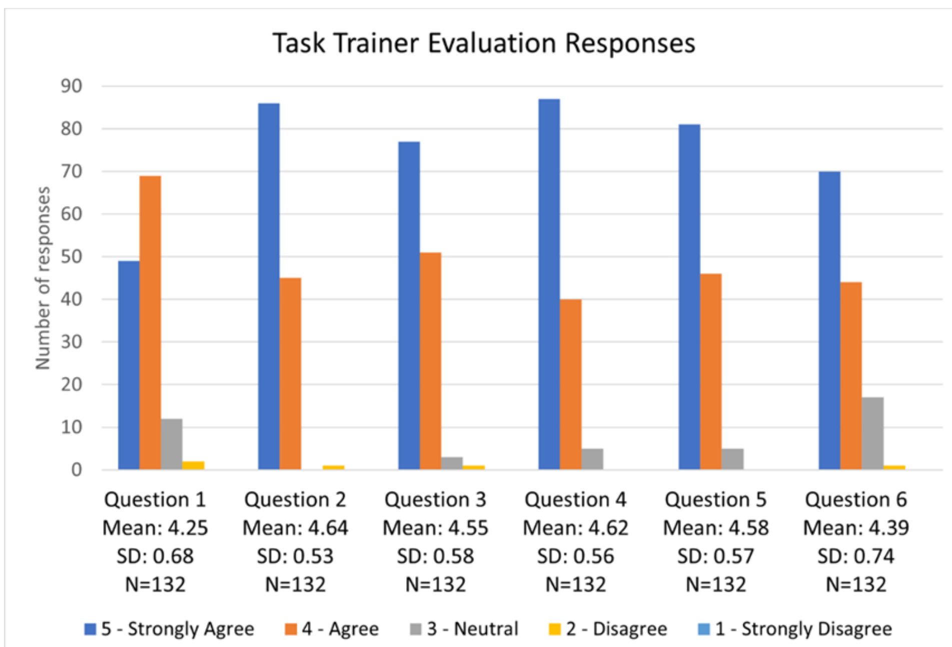
We had 177 medical learners and clinicians participate in simulations using the task trainers. Of these, 132 completed the survey, with a response rate of 75%. The health care specialty and level of education of the participants who completed the study included 72 medical students, 14 resident physicians, 3 OB-GYN clinicians, 2 OB-GYN nurse practitioners, five certified nurse midwives, 13 nurse practitioner students, and 23 family medicine resident physicians. The survey findings indicated that the simulation effectively mirrored real-life scenarios, prepared learners for actual procedures, and provided valuable practice with medical instruments. Learners reported successful completion of the gynecologic procedures during the simulation sessions. Data also highlighted that using the task trainer contributed to an enhanced learning experience, increased comfort with performing the procedures, and could facilitate improved communication with patients.

One question in the survey had the option of choosing all that apply. In this question, the respondents were asked to indicate what educational level they thought the task trainer would be most suitable for. Options included medical students, nurse practitioner students, resident physicians, and clinicians. Overall, the responses indicated that the task trainer would be most suitable for learners in the first stages of training. Seventy-eight percent of responders indicated that medical and nurse practitioner students were the most appropriate learners for using the task trainers. Sixty-six percent of responders indicated that the first-year resident physician level would be the most appropriate level for learning with the task trainer.

As shown in Figure 3, the participants' responses to the six research questions showed a high level of agreement.

Figure 3: Task Trainer Evaluation Responses

The responses to the task trainer evaluation questions show a high level of agreement. The statements and questions included:



Question 1: The gynecological simulator provides a realistic patient simulation of the internal female pelvic anatomy.

Question 2: I was able to successfully complete the procedures using the gynecological simulator.

Question 3: After using the gynecological simulator, I feel more prepared to perform the procedures in “real-life” clinical settings.

Question 4: Overall, the use of the gynecological simulator enhanced my learning.

Question 5: The gynecological simulator provides a more realistic opportunity for the learner to identify and utilize various medical tools and equipment during simulation sessions.

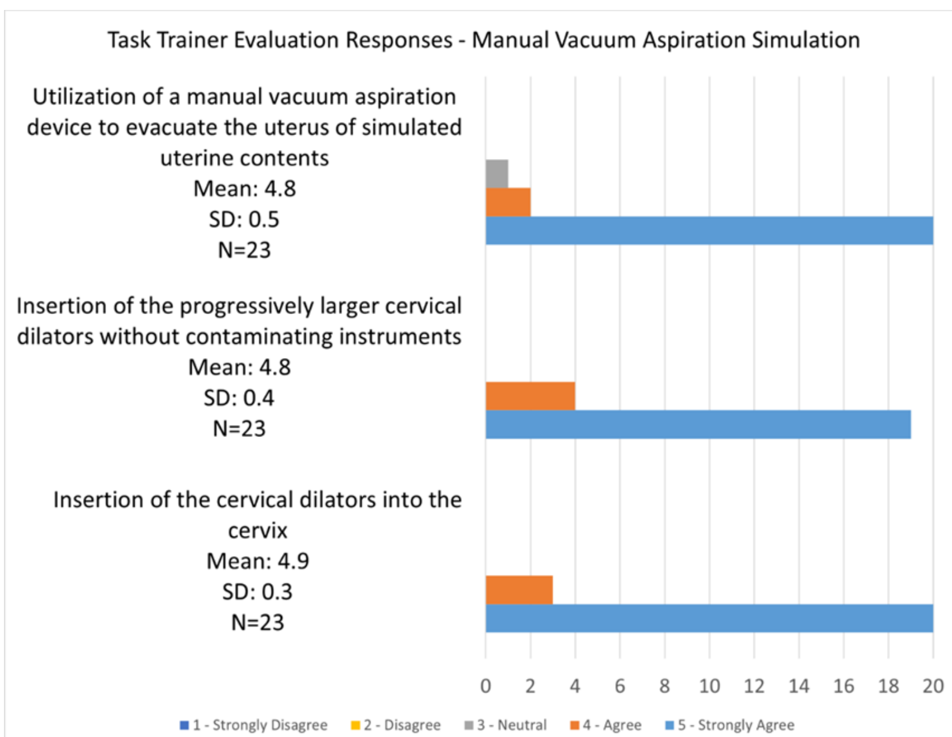
Question 6: Would repetitive practicing with this model allow you to become more comfortable with the procedure and better communicate with the patient during the procedure?

The average of all six task trainer evaluation questions is 4.5, establishing a strong consensus among participants. The standard deviation of 0.53-0.74 suggested low variability in the responses. This supported the coherence of the findings. The uniformity of participant perspectives enhances the robustness and reliability of the study's outcomes.

For those learners who completed the manual vacuum aspiration procedure, there are an additional three questions on the survey, and they are also measured on a Likert scale of 1-5. Twenty-three learners completed those questions. The average Likert score for all three questions was 4.8, with a standard deviation of 0.3-0.5 (Figure 4).

Figure 4: Task Trainer Evaluation Responses – Manual Vacuum Aspiration Simulation

The learners who performed the manual vacuum aspiration procedure completed an additional three questions for the prompt: I was able to successfully perform these procedures using the gynecological simulator model for the manual vacuum aspiration. These responses show a high level of agreement.



These responses also showed a high level of agreement with a strong consensus. The standard deviation suggested a low level of variability in the responses.

Comments for the qualitative components of this project were captured via an open-ended question. One researcher attended each simulation and took field notes that consisted of the simulation date, the number of learners, the instructor's name, the procedures performed, and verbal comments regarding the simulation sessions and the task trainer. Positive comments recorded included: “Great representation of the real thing.” “I think this was much more realistic than previously used methods.” “This was awesome!” “Fun and educational,” and “I really appreciated how the inside of the uterus even had what resembled to be uterine lining tissue that could be aspirated with the endometrial biopsy tools. Additionally, the task trainer was very helpful when learning how to use the different IUDs. Would highly recommend its continued usage.”

Participants in the simulations overwhelmingly expressed positive feedback. They appreciated the ability to retrieve simulated uterine tissue/contents during the procedures. They valued the realism of being able to apply the tenaculum to the cervix and apply gentle traction. Additionally, there was consensus that this small, cost-effective task trainer would benefit low-resource clinical and educational settings. Having the task trainer available in the clinic was deemed valuable for just-in-time teaching opportunities with students. Some constructive criticism included: “It would be nice to have a cervicovaginal junction to practice paracervical blocks before the procedure.” “If the PVC pipe simulating the vaginal vault had a silicone lining, it would help keep the speculum from slipping out.” “The simulator does not have vaginal walls + uterus is immobile plastic,” but this person also added, “Still very useful for practice even with the things noted above.”

Discussion

We created a novel 3D-printed gynecological task trainer and paired it with commercially available PVC plumbing components to make a tabletop task trainer. The trainer is simple to set up, and the components can be repeatedly used and easily cleaned with soap and water. The low cost and tabletop design allow simulations to be performed in groups, with two learners per task trainer. Creating a silicone cervix and 3D printing the three additional parts of the gynecological simulator takes time and resources. However, these components may be used for many simulation sessions. Because a single-toothed tenaculum is applied to the silicone cervix in many of the procedures, this portion of the model may need to be replaced eventually. For this study, the gynecological task trainers were each used in an average of 18 simulation sessions. The cervices remained in good working condition after the study.

A survey was used to collect data from learners, which is a cost-effective and time-efficient data collection method. A large and diverse sample population was used, providing a broad perspective on this topic. The study became both interprofessional and multidisciplinary with the addition of nurse practitioner students and family medicine residents. The survey's nature facilitated a structural analysis of the data, which aided in identifying agreement with the task trainer evaluation questions. The survey was anonymous, which promoted honest and candid responses. There was a high response rate, likely due to the survey being easy to access via a QR code on the task trainer base. Having one researcher attend each simulation session allowed for an additional collection of insightful verbal comments about the design and potential uses of the task trainer.

Preparation for real-life procedures was significantly enhanced through the utilization of the novel 3D-printed task trainers in simulation sessions. This innovative approach has proved invaluable for students' and medical professionals' education and skill development. It offered a safe and supervised environment for hands-on learning. The task trainer facilitated the efficient development and refinement of essential skills and allowed learners to practice without exposing actual patients to potential risks. This method contributed to a more comprehensive understanding of gynecologic procedures. It helped ensure that medical practitioners entered real-life scenarios with a heightened proficiency and confidence in performing gynecologic procedures on patients.

Developing greater proficiency is a direct outcome of deliberate practice within a controlled and supervised environment, where learners can build confidence and hone their skills in executing procedures. This form of experiential learning prepares them for analogous scenarios in actual clinic settings and effectively alleviates performance anxiety. The secure environment of simulations allows learners to focus on refining their skills without the pressures associated with live procedures, enhancing their comfort levels and ensuring a smoother transition to real-world scenarios.

Conclusion

We successfully designed, implemented, and evaluated a novel 3D-printed gynecological task trainer. Through an online survey, we concluded that this task trainer is a valuable tool for teaching and learning medical procedures during simulation sessions. This cost-effective task trainer allows for the efficient replicating of various gynecological procedures, facilitating enhanced learning opportunities. Its simplicity allows for easy replication and tabletop placement, enabling the creation of multiple models for use in group simulations. This approach proves to be highly efficient in achieving impactful and high-yield simulation sessions. The results from this quality improvement project reinforce that using a low-cost, versatile 3-D printed task trainer enhances learning and allows the completion of various standard gynecological procedures. It provides realistic simulations that allow medical equipment use and prepare the learner for real-life procedures. As the learner becomes more comfortable performing these gynecological procedures, communication with the patient will inevitably improve.

Several limitations to this quality improvement project exist. First, it was a single-site study. Second, the evaluation tool was a survey only, with the addition of some field notes. Third, human factors, such as ergonomics, were not assessed. Continued revisions and improvements in the design of this initial gynecological task trainer are planned, as biological systems engineering students have joined the team to enhance the design while retaining the functional aspect of the initial model. Detailed instructions, including the 3D-print files to create the task trainer, may be accessed at https://digitalcommons.unmc.edu/com_obgyn_pres/1/.

Acknowledgments

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Financial Disclosure Summary

There are no financial conflicts of interest to disclose.

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Table 1: Gynecological Task Trainer Equipment Supply List and Costs
This list contains the items needed to create the gynecological task trainer. These costs were obtained from online retailers on 11/09/2023.

Item	Cost total	Cost each
Wood shelf board or similar, 72 inch length x 12 inch depth (cut to 12 x 12 inch, yield 6 bases)	$17.98	$3.00
PVC pipe 1.5 inch x 24 inch (cut into 6" lengths, yield 4 pieces)	$4.21	$1.05
Charlotte pipe 1.5" x 2" PVC SWV Hub x Hub Increaser/Reducer Coupling, 1 piece	$2.24	$2.24
Charlotte pipe 2" x 2" x 1.5" PVC DWV sanitary tee, 1 piece	$3.54	$3.07
Silicone and dye 3 ounces of silicone per cervix Very small amount of dye per cervix	Ecoflex 00-20 – cost depends on the unit purchased Silc Pig Blood 4 oz $35.59	$3.00
Filament for 3D printed items: Solid and translucent polyactic acid (PLA) costs about $0.65/ounce 3D-printed cervix mold 1.34 ounces/38g of PLA		$0.87
3D-printed uterus 1.69 ounces/48g of translucent PLA		$1.10
3D-printed outer ring 1.24 ounces/35g of PLA		$0.79
Thick-It, water thickening agent to make the gel that is placed in the uterus to represent tissue Red food coloring	Thick-It 10 oz container $9.93, use approximately 0.25 oz per uterus. Cost per uterus: $0.25. Red food coloring 1 oz container $2.30, very small amount of food coloring; just enough to make the gel pink. Cost per uterus: $0.01	$0.26
	Total cost for one model:	$15.38

Table 2: Gynecological Procedures Survey Questions
I consent to participating in this research study. Yes or No

1. Please select your healthcare specialty:
   a. OB-GYN
   b. Family Medicine
   c. Internal Medicine
   d. Nursing
   e. Other
2. Please select your level of education:
   a. Third-year medical student
   b. Fourth-year medical student
   c. Resident
   d. Nurse practitioner student
   e. Nurse practitioner
   f. DNP
   g. Midwife
   h. MD/DO
   i. Other: please state your level of education
3. What levels of learners would this model be appropriate for (select as many as desired)?
   a. M3
   b. M4
   c. Nurse practitioner student
   d. HOI
   e. HOII
   f. HOIII
   g. HOIV
   h. Clinician

Please answer the following questions pertaining to the gynecological simulator:
5 - Strongly agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly disagree

1. The gynecological simulator provides a realistic patient simulation of the internal female pelvic anatomy. *
2. I was able to successfully complete the procedures using the gynecological simulator.
3. After using the gynecological simulator, I feel more prepared to perform the procedures in "real-life" clinical settings. *
4. Overall, the use of the gynecological simulator enhanced my learning. *
5. The gynecological simulator provides a more realistic opportunity for the learner to identify and utilize various medical tools and equipment during simulation sessions.
6. Would repetitive practicing with this model allow you to become more comfortable with the procedure and better communicate with the patient during the procedure?
7. Text box - If you marked disagree or strongly disagree on the questions above, what challenges arose?
8. Text box - Please provide comments on any of the questions above or the design of the gynecological simulator:

* These survey questions were selected and modified from the instrument described by Abdo AR, Ravert P. Student satisfaction with simulation experiences. Clinical Simulation in Nursing. 2006;2.

Additional questions for those who performed the manual vacuum aspiration procedure:
5 - Strongly agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly disagree
I was able to successfully perform these procedures using the gynecological simulator:

1. Insertion of the cervical dilators into the cervix
2. Insertion of progressively larger cervical dilators without contaminating instruments
3. Utilizing a manual vacuum aspiration device to evacuate the uterus of simulated uterine contents