



Experiential learning in urologic single-port robotic surgery transition training: a qualitative descriptive study

Young Gyu Kwon¹ · Se Young Choi² · Hye Young Park³ · Yu Seob Shin⁴ · Chan Woong Kim^{1,5,6,7}

Received: 17 April 2026 / Accepted: 4 May 2026
© The Author(s) 2026

Abstract

Transitioning from multi-port to single-port robotic systems in urologic surgery requires significant team adaptation; however, the experience of clinicians during this shift remains underexplored. Therefore, this study aims to examine the effect of single-port transition training on learning experiences and perceived readiness among healthcare providers, using Kolb's experiential learning theory. Eleven physicians and 22 operating room nurses completed phased single-port transition training at a university hospital in Seoul (February–May 2025) and responded to open-ended questionnaires analyzed using Braun and Clarke's thematic analysis. Most experiences aligned with Kolb's learning cycle: concrete experience with single-port articulation, reflective comparison of single- and multi-port routines, abstract conceptualization of single-cannula principles, and active experimentation with collision prevention and workflow strategies. Some experienced physicians reported limited learning gains, suggesting that prior expertise reduces engagement. Nurses emphasized docking efficiency and spatial management, whereas physicians prioritized articulation control and technique refinement. Both groups reported greater confidence and interprofessional coordination. These findings suggest that integrating hands-on practice with structured reflection supports adaptation; however, the relationship between perceived readiness and clinical performance requires further investigation.

Keywords Single-port robotic surgery · Experiential learning · Training · Qualitative research · Urology

Young Gyu Kwon and Se Young Choi contributed equally to this work.

✉ Chan Woong Kim
whenever@cau.ac.kr

- ¹ Center for Chung-Ang Medical Education Resource Allocation (CAMERA), College of Medicine, Chung-Ang University, Seoul, Republic of Korea
- ² Department of Urology, Chung-Ang University Hospital, Chung-Ang University College of Medicine, Seoul, Republic of Korea
- ³ Robot Surgery Center, Chung-Ang University Hospital, Seoul, Republic of Korea
- ⁴ Department of Urology, Jeonbuk National University Medical School, Jeonju, Republic of Korea
- ⁵ Department of Emergency Medicine, College of Medicine, Chung-Ang University, Seoul, Republic of Korea
- ⁶ Center for Medical AI Research and Education (CAU-MEDAI), Chung-Ang University, Seoul, Republic of Korea
- ⁷ Department of Emergency Medicine, Chung-Ang University Hospital, Chung-Ang University College of Medicine, Seoul, Republic of Korea

Introduction

Robotic surgery is a key innovation in minimally invasive procedures and a standard treatment modality for major malignancies in urology, gynecology, and general surgery [1, 2]. In the Republic of Korea, its use has expanded rapidly since its introduction in 2005 [3]. Early development focused on multi-port (MP) systems; however, recent advances have shifted attention to single-port (SP) platforms, enabling single-incision surgery with less invasiveness and better cosmetic outcomes [4]. A systematic review shows that SP platforms have safety and efficacy comparable to those of conventional MP approaches, with potential advantages in cosmetic satisfaction and reduced postoperative pain [5].

The da Vinci SP system inserts three robotic arms and a camera through a single cannula, improving access to confined anatomical spaces such as the deep pelvis in radical prostatectomy and the retroperitoneum in partial nephrectomy [6, 7]. Unlike MP systems with independently moving arms, SP systems require articulating instruments to

be manipulated in confined spaces, necessitating different spatial perception and instrument-control skills [8]. Additionally, the single-cannula configuration alters team positioning, port-site access, and intraoperative coordination, requiring individual skill adaptation and team-wide adjustments in communication and workflow.

These platform-specific demands create educational challenges, as MP-oriented training may not cover competencies required for SP practice. SP transition training typically combines simulation-based skill drills, hands-on practice with animal tissue models, and team-based rehearsals designed to develop SP-specific competencies in instrument articulation, docking, and workflow coordination. Effective robotic surgery requires advanced spatial perception, refined hand–eye coordination, and coordinated team-based performance [9, 10]—competencies that warrant structured training rather than simple skill transfer [11]. In robotic surgery, perioperative nurses perform critical functions, including system docking and undocking, instrument exchange, intraoperative troubleshooting, and real-time spatial coordination with console surgeons. These responsibilities expand substantially during SP procedures owing to the constrained single-cannula workspace and altered port-site geometry. However, current curricula primarily emphasize simulator-based technical skill acquisition and individual performance metrics [12, 13], with limited emphasis on team adaptation to new platforms. Although emerging evidence suggests that interdisciplinary robotic surgery training improves workflow efficiency and reduces procedural errors [14, 15], systematic reviews report a persistent gap between team-level challenges and available interventions in robotic-assisted surgery [16]. Previous survey-based research identifies barriers in robotic surgery training, including limited hands-on exposure and limited trainee autonomy [17, 18]; however, studies qualitatively examining the transition from the perspective of the entire surgical team remain limited.

Kolb's experiential learning theory [19] holds that effective learning follows a four-stage cycle—concrete experience, reflective observation, abstract conceptualization, and active experimentation—turning experience into practical wisdom [20]. Robotic surgery education aligns with this framework by integrating simulation-based practice, structured feedback, conceptual learning, and supervised clinical application [21]. Despite this alignment, empirical studies examining the experience of healthcare providers with robotic surgery education remain limited. Existing research primarily focuses on the technical skill acquisition of surgeons [22, 23] rather than that of the entire surgical team, including nurses in essential perioperative roles [24, 25]. Qualitative research on the adaptation of perioperative nurses to robotic surgery highlights challenges, including role ambiguity, insufficient training, and technology-related

stress [26, 27], highlighting the need to examine physician and nurse perspectives during platform transitions.

Therefore, this study aims to examine the effect of SP robotic surgery education on the learning experiences of healthcare providers, using Kolb's experiential learning theory. It addresses three questions: (1) How do SP transition training experiences align with Kolb's experiential learning cycle? (2) What educational outcomes result from experiential learning? (3) How do learning experiences differ between physicians and nurses?

Addressing these questions is essential for developing evidence-based curricula that support safe and effective team-based adoption of emerging SP platforms, particularly as institutions increasingly transition from established MP systems.

Materials and methods

Study design and setting

In this qualitative descriptive study, the learning experiences of healthcare providers during early SP robotic system adoption, grounded in pragmatic epistemology and guided by Kolb's experiential learning theory, were investigated [28, 29]. A qualitative descriptive design was used to capture the subjective accounts of training experiences of participants in their own terms rather than to generate theory or interpret the essence of lived experience. A single-site design enabled in-depth exploration in a consistent institutional and curricular context during early adoption.

The study was conducted between February and May 2025 at a 700-bed tertiary center in Seoul that performs over 700 robotic surgeries annually. After introducing the da Vinci SP system alongside the existing Xi system, the institution implemented targeted transition training based on the da Vinci Technical Training Pathway (Intuitive Surgical Korea, Inc., Seoul, Republic of Korea). This study focused on initial transition phases—didactic instruction, simulation, and supervised rehearsal—excluding later surgeon-led mentorship stages (TR-200 to TR-500). One investigator (S.Y.C.) was the lead SP surgeon, while two (Y.G.K. and C.W.K.) had no direct program involvement, enabling insider and outsider perspectives.

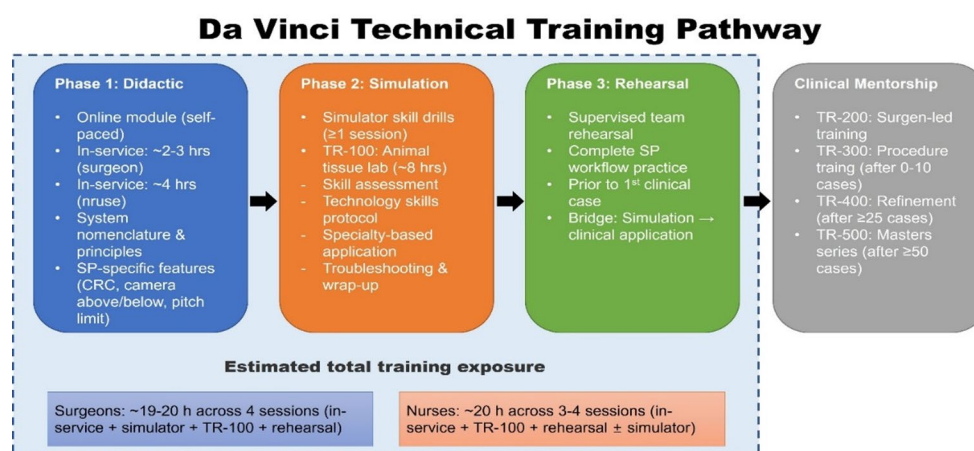
Participant selection and characteristics

Criterion-based purposive sampling was used to recruit all physicians and operating room (OR) nurses who completed SP transition training during the study period; inclusion criteria were (1) SP training completion during the study period, (2) current or anticipated involvement in robotic

Table 1 Participant characteristics

Characteristic	Physicians (n=11)	Nurses (n=22)
<i>Sex, n (%)</i>		
Female	1 (9.1)	19 (86.4)
Male	10 (90.9)	3 (13.6)
<i>Clinical experience, years</i>		
Median (range)	10 (1–20)	5.5 (1–18)
≤5 years, n (%)	3 (27.3)	12 (54.5)
6–10 years, n (%)	3 (27.3)	5 (22.7)
11–20 years, n (%)	5 (45.5)	5 (22.7)

Fig. 1 Overview of the da Vinci technical training pathway and study scope. Note: The training pathway comprised three phases examined in this study (didactic, simulation, and supervised rehearsal) and subsequent clinical mentorship stages (TR-200 to TR-500) beyond the study scope. Role-specific training hours and session structures are indicated for surgeons and nurses. SP, single-port; CRC, custom remote center; TR, training; h, hours



surgery workflows, and (3) questionnaire completion. Exclusion criteria included individuals without perioperative roles and questionnaires lacking sufficient content for coding. Of the 38 eligible personnel, 33 returned completed questionnaires (86.8% response rate), including 11 physicians and 22 OR nurses. The sample size was guided by the concept of information power, based on the narrow study aim, specific participant group, and theory-informed analytical framework [29]. Table 1 summarizes participant characteristics.

Training program curriculum

The training program followed the da Vinci Technical Training Pathway, comprising three sequential phases (Fig. 1).

The didactic phase comprised online modules followed by on-site sessions (2–3 h for surgeons; 4 h for nurses) covering system operations, including the custom remote center (CRC), and navigator interpretation for nurses.

The simulation phase included simulator drills and a full-day animal tissue laboratory (TR-100, ~8 h) focused on articulation, suturing, energy application, and dissection skills.

The supervised rehearsal phase bridged simulation and independent practice through team-based rehearsals preceding the first clinical case.

Surgeons received approximately 19–20 h of training, and nurses received 20 h across 3–4 sessions (Fig. 1).

Table 2 compares MP and SP curricula based on system type and professional role.

All sessions were led by certified clinical application specialists under the supervision of experienced console surgeons. Completion required fulfilling all components sequentially, including simulator proficiency benchmarks, TR-100 completion, and rehearsal participation. No formal pass/fail threshold was set; real-time instructor feedback was the primary method for identifying skill deficits.

Data collection

Data were collected using structured open-ended questionnaires administered in person on paper within the institutional educational quality assurance process. Questionnaires were distributed by two investigators (Y.G.K. and C.W.K.), not involved in training delivery, with voluntary participation and no effect of responses on training evaluation. Written questionnaires were used instead of interviews to accommodate clinical scheduling constraints [30], allow reflective responses [31], and minimize social desirability bias in hierarchical clinical settings [32].

Questionnaire items were developed from Kolb's four experiential learning stages, supported by a literature review and consultation with three experts in medical education and robotic surgery. Items were refined through pilot testing with three healthcare providers excluded from the main analysis, with feedback leading to the rewording of two

Table 2 Comparison of da Vinci robotic surgery training curricula based on system type and professional role

Component	^a MP	SP
<i>Panel A: Surgeon Training Curriculum</i>		
Target participants	Surgeons intending to perform MP robotic surgery	Surgeons intending to perform SP robotic surgery (typically with Xi experience)
Educational objectives	Understanding MP system characteristics	Understanding SP system characteristics
Theoretical education	Online training module completion	Online training module completion
System in-service	(1) Patient cart: arm/port clutch, port placement, I&A introduction, endoscope features, instrument insertion/removal, and fault recovery; (2) Surgeon console: basic information, pedal control, endoscope control, and touchpad	(1) Patient cart: all MP components plus CRC, camera positioning, and arm pitch limits; (2) Surgeon console: basic information, pedal control, SP concepts; (3) Console mode practice, and touchpad
Skills drills	Simulator training: range of motion, suturing practice, sea spikes, energy application, advanced techniques, and node/vessel dissection	Simulator training: range of motion, suturing practice, sea spikes, energy application, ring roller coaster, and node/vessel dissection
<i>Panel B: Nurse Training Curriculum</i>		
Target participants	Nurses participating in MP robotic surgery	Nurses participating in SP robotic surgery (most with Xi training experience)
Educational objectives	(1) General robotic surgery concepts; (2) Xi system understanding; (3) Assistant role acquisition	(1) SP system understanding; (2) Assistant role acquisition
Theoretical education	Online training module; on-site lecture	Online training module; on-site lecture
Training agenda	(1) Robot-assisted surgery overview; (2) da Vinci Xi system overview; (3) da Vinci Xi system docking practicum	(1) da Vinci SP system overview; (2) da Vinci SP system docking practicum; (3) Navigator interpretation

^aMP, multi-port; SP, single-port; I&A, instruments and accessories; CRC, custom remote center. The training program was conducted in collaboration with Intuitive Surgical, Inc

items for clarity. Separate questionnaires were developed for physicians and nurses.

The physician questionnaire comprised five open-ended items addressing: (1) memorable learning experiences; (2) knowledge and skills acquired and their clinical application; (3) strengths and limitations of practice-centered training; (4) learning barriers; and (5) suggestions for program improvement. The nurse questionnaire included parallel items adapted to perioperative responsibilities; item 4 was modified to address perceived changes in professional expertise and team collaboration, reflecting the central role of interprofessional coordination in bedside nursing practice during robotic surgery. This role-specific adaptation was informed by literature indicating that the learning needs of perioperative nurses in robotic surgery are closely linked to team dynamics and workflow coordination [24, 27], whereas the learning challenges of physicians are more frequently related to individual skill acquisition and prior expertise [17, 18]. Both questionnaires captured sex and years of clinical experience (Supplementary Material 1).

Questionnaires were distributed within 1 week after training completion. Participants completed them individually in 20–30 min. Responses were collected in Korean and translated into English using a consensus-based process: a bilingual researcher (Y.G.K.) performed the initial forward translation, and a second bilingual team member (S.Y.C.) independently reviewed it against the original Korean text. Discrepancies were resolved through discussion until consensus was achieved. Although a formal back-translation was not performed, the dual-reviewer process ensured that

translated quotations preserved the meaning and nuance of the original responses.

While written questionnaires do not allow real-time probing as interviews, the structured open-ended format with multiple items per domain elicited substantive responses from most participants. Adequacy of data depth was assessed during analysis; responses comprising single-word answers or minimal content ($n = 3$ items across all participants) were retained for coding but classified as thin data segments.

Data analysis

Data were analyzed using Braun and Clarke's six-phase thematic analysis [33]: familiarization, initial coding, theme development, theme review, theme definition and naming, and report production. A hybrid inductive–deductive approach was used, with Kolb's experiential learning cycle serving as a deductive sensitizing framework, while subthemes emerged inductively from the data. Coding was performed manually using Microsoft Word and Excel (Microsoft Corporation, Redmond, WA, USA), selected for accessibility and transparency in maintaining an audit trail of coding decisions.

Three researchers independently reviewed de-identified responses and generated initial codes, yielding 142 codes across the three coders. Codes were compared during iterative meetings (four meetings over 6 weeks); discrepancies were resolved through consensus, resulting in 47 unique codes.

Conceptually related codes were grouped into candidate themes, reviewed for coherence, and defined. While Kolb's experiential learning cycle guided the overall thematic structure, subthemes were derived inductively, and data not aligning with the framework were not forced into it (Fig. 2).

Methodological rigor

Trustworthiness was ensured using Lincoln and Guba's criteria [34]. Credibility was established through investigator triangulation: three researchers with complementary expertise—medical education and qualitative methodology (Y.G.K.), clinical urology with SP experience (S.Y.C.), and simulation-based education (C.W.K.)—independently coded the data and refined interpretations through consensus. To reduce social desirability bias, one researcher conducted SP training, while two other researchers distributed and collected anonymous questionnaires. Member checking was not performed because the anonymous questionnaire design precluded respondent re-identification; instead, credibility was strengthened through investigator triangulation and iterative consensus coding. Transferability was supported through a thick description of the training context,

participant characteristics, and institutional setting, enabling readers to assess applicability in other contexts.

Results

Experiential learning through single-port robotic transition training

Concrete experience: embodied exposure to unfamiliar technical ecology

Participants consistently identified hands-on engagement with the SP platform as the primary learning entry point. This concrete experience involved SP-specific articulation within the constrained single-cannula workspace, distinct from routine MP practice. Many accounts highlighted embodied learning and the recalibration of sensorimotor expectations rather than simple knowledge acquisition.

Direct operation of the da Vinci system, replacing robotic arm manipulation, and learning through hands-on interaction enhanced understanding and facilitated practical application. (Nurse 1, 10 years)

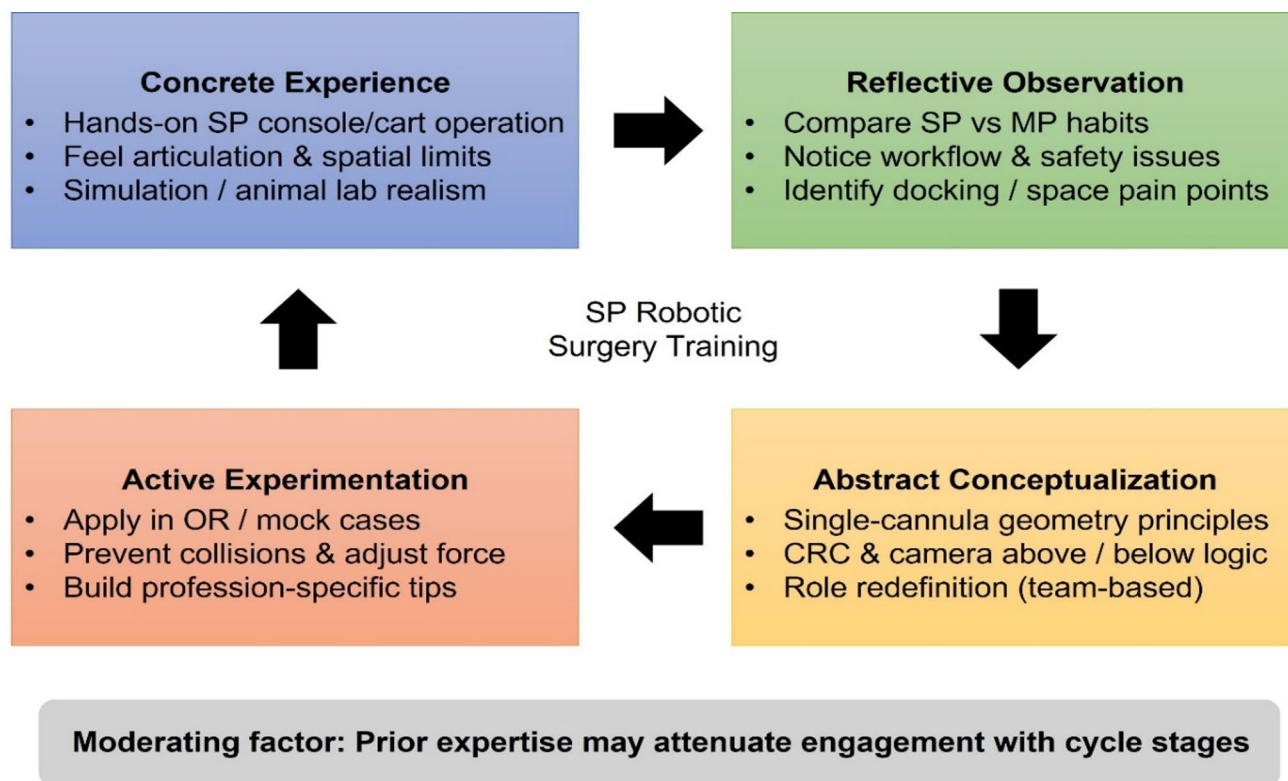


Fig. 2 Mapping of Kolb's experiential learning cycle to SP robotic transition training. Participant learning narratives were structured into the following four iterative stages: concrete experience (hands-on SP console engagement), reflective observation (comparison of SP versus MP practices), abstract conceptualization (formulation of single-

cannula constraints and role adjustments), and active experimentation (application of strategies in the OR). A subset of experienced practitioners reported limited engagement with the full cycle (Sect. 3.6). SP, single-port; MP, multi-port; OR, operating room; CRC, custom remote center

Nurses reported that lecture-based instruction alone did not provide the practical readiness achieved through hands-on experience. Physicians described the concrete experience as a safe environment for practicing SP-specific challenges, including instrument collision and restricted working angles.

Simulation training using the robot was highly engaging; displaying scores fostered competitiveness and enabled tracking of skill progression. (Physician 4, 4 years)

Practicing with animal models simulating realistic clinical environments was particularly informative. (Physician 9, 20 years)

Reflective observation: reframing multi-port habits

After hands-on exposure, participants reflected on differences between the MP and SP systems, identifying habits that were ineffective under SP constraints. Nurses emphasized safety and workflow stability, highlighting increased sensitivity to docking and spatial positioning.

Careful consideration of patient positioning and docking location enabled safer surgeries. (Nurse 2, 15 years)

Physicians highlighted adaptation of techniques, especially fine motor control and suturing. Reflective observation served as a bridge between action and understanding, enabling participants to distinguish skills transferable from MP systems from those requiring relearning for SP systems.

Abstract conceptualization: formulating principles under single-cannula constraints

Hands-on engagement followed by reflection led to the development of new operational principles. Nurses described a shift from passive support to proactive system management.

Increased understanding of the robotic system enabled anticipation of a transition from passive participation to active contribution. (Nurse 7, 2 years)

Physicians conceptualized principles including alignment, remote center logic, and collision geometry. Concepts such as the CRC served as anchors for understanding performance failures and prevention strategies.

Understanding the CRC highlighted the importance of accurate alignment. (Physician 8, 3 years)

Overall, abstract conceptualization encompassed cognitive understanding, role clarification, and insight into SP-specific coordination patterns distinct from MP systems.

Active experimentation: translating principles into operating-room strategies

Participants applied newly formulated principles through active experimentation in clinical or near-clinical settings. Nurses developed bedside strategies, including instrument insertion management and optimization of spatial coordination.

When instrument insertion was difficult, applying methods learned during training enabled easier insertion. (Nurse 21, 4 years)

Physicians described experimentation as MP technique adaptation to SP mechanics, refinement of motion economy, and consolidation of control strategies.

Through training, previously vague concepts became concrete, supporting adaptation from MP to SP surgery. (Physician 5, 10 years)

Across professions, active experimentation completed the learning cycle by translating new understanding into actionable routines, with confidence increasing as strategies were tested and validated.

Outcomes observed across the experiential learning cycle

Professional capability development

Participants reported growth in technical familiarity, workflow competence, and interprofessional coordination. Nurses associated increased understanding of the robotic system with expanded bedside roles, while physicians emphasized that training facilitated structured integration of SP-specific innovations.

As understanding of the robotic system increased, scrub nurses adjusted robotic arms, supporting smoother interprofessional cooperation. (Nurse 20, 1 year)

The training enabled systematic learning of SP features, progressing from foundational functions to advanced capabilities. (Physician 11, 10 years)

Psychological readiness and confidence

Confidence increased as participants transformed unfamiliar tasks into experiential familiarity through hands-on practice and reflective learning. This confidence was attributed to specific experiential mechanisms, including practice, troubleshooting, and guidance-based learning strategies.

Acquiring professional tips enhanced confidence in performing docking procedures successfully. (Nurse 19, 3 years)

Teamwork and shared mental models

Participants valued joint training for clarifying role-specific constraints and aligning expectations. Collaboration improved through shared experience, reflection, and practice—representing an interprofessional application of the experiential learning cycle.

During actual surgery, joint training facilitated smoother workflow progression and enhanced collaborative problem-solving. (Nurse 1, 10 years)

Performing mock surgery with the console surgeon clarified challenges experienced by nurses and improved communication expectations. (Nurse 21, 4 years)

Physicians also recognized the importance of team coordination. One physician emphasized the need for expanded collaborative training: “Future training should provide more opportunities for surgical assistants” (Physician 9, 20 years), acknowledging that effective SP adoption depends on coordinated interprofessional preparation. As noted in the Methods section, the physician questionnaire focused on individual learning barriers rather than team collaboration, reflecting the console-based nature of the surgeon role, whereas the nurse questionnaire included a dedicated item on professional role and collaboration, consistent with the interprofessional bedside practice demands. This role-specific questionnaire design may partly explain the greater emphasis on teamwork narratives among nurses in this subsection.

Profession-specific learning patterns

Learning priorities differed based on professional role: nurses focused on bedside workflow and space management, while physicians emphasized technical refinement and precision control at the console. Figure 3 illustrates differences across primary focus areas, learning mechanisms, and outcomes, highlighting shared benefits including increased confidence, enhanced interprofessional collaboration, and safer SP adoption.

Rather than mastering isolated tasks, nurses described SP adoption as transforming the entire perioperative workflow, requiring system-wide understanding and anticipatory coordination. Conversely, physicians emphasized technical refinement under SP-specific constraints, including articulated joint control, collision avoidance, and fine motor calibration.

Improperly performed motions increased the risk of damage to surrounding structures. The structured apparatus for practicing challenging movements was particularly valuable. (Physician 10, 4 years)

Conditions associated with effective learning

Participants identified training features supporting progression through the experiential learning cycle. Structured sequencing and progress tracking facilitated abstract conceptualization, while hands-on practice enabled learning beyond self-study. Additionally, real-time instructor guidance enhanced sustained focus and enabled rapid adjustment, aligning with reflective observation and active experimentation.

Operating equipment with real-time guidance provided immediate feedback, enabling visual learning through practice. (Nurse 13, 6 years)

Areas for improvement

For routine practice, participants emphasized the need for more frequent training, as single sessions were considered insufficient. Expanding team-based training components was perceived as important for strengthening shared mental models and coordinated responses.

Deployment after a single training session was challenging; nurses require sufficient practice and exposure to different surgical cases. (Nurse 10, 12 years)

Future training should provide more opportunities for surgical assistants. (Physician 9, 20 years)

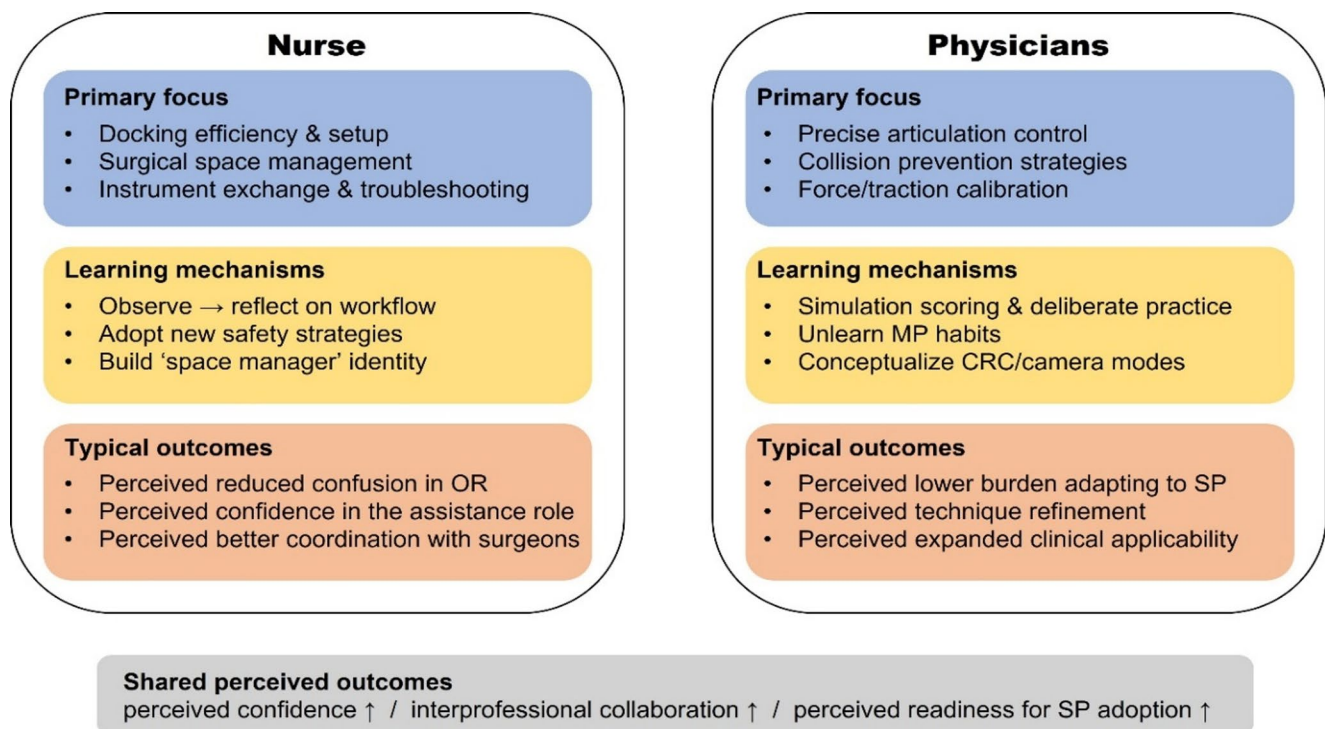


Fig. 3 Profession-specific learning patterns observed in SP robotic transition training. Nurses focused on docking efficiency, surgical space management, and troubleshooting, while physicians empha-

sized articulation control, collision prevention, and force calibration. OR, operating room; MP, multi-port; CRC, custom remote center; SP, single-port

Table 3 presents representative quotations mapped to Kolb's four experiential learning stages based on professional group, including responses outside the theoretical framework.

Data not aligning with Kolb's experiential learning cycle

While most participant narratives aligned with Kolb's four-stage framework, a subset did not clearly fit within the experiential learning cycle. These responses were separately coded to maintain analytical transparency.

First, several experienced physicians (≥ 10 years of robotic surgery experience) reported limited perceived learning gains from the training program. One physician noted: "Since I already had extensive robotic surgery experience, the training served more as a refresher than a significant educational experience" (Physician 11, 10 years). Another stated: "The training content was relatively simple and straightforward; nothing was particularly noteworthy" (Physician 2, 18 years). A third observed: "No substantial difference was perceived compared with other surgical training programs" (Physician 3, 20 years).

Second, one physician explicitly identified prior MP expertise as a barrier to engagement: "The overconfidence from extensive MP experience—assuming SP would not be

significantly different—hindered learning" (Physician 5, 10 years).

Third, some responses focused primarily on logistical and practical concerns—including scheduling difficulties, travel burden to training centers, and time constraints for completing required modules—rather than on learning processes.

In summary, three categories of responses fell outside Kolb's four-stage framework: limited perceived learning gains among experienced physicians, prior expertise as a barrier to engagement, and logistical concerns unrelated to learning processes.

Discussion

Theoretical contributions

This study provides qualitative evidence supporting Kolb's experiential learning theory as a robust framework for understanding the transition to SP surgery. The findings indicate that this transition extends beyond technical skill acquisition to include unlearning established MP practices and reorganizing sensorimotor coordination for single-canula geometry. Most learning narratives followed the four-stage experiential cycle.

Table 3 Representative participant quotations mapped to experiential learning themes based on the professional group

Kolb's experimental learning stage	Professional group	Representative quotation
Concrete experience	Nurse	"Direct operation of the da Vinci robot, replacing robotic arms, and hands-on interaction, enhanced understanding, and facilitated practical application." (Nurse 1, 10 years)
	Nurse	"The training allowed in-person practice with the robotic system, which was beneficial. In routine hospital settings, time constraints limited such hands-on opportunities, but the training provided sufficient hands-on experience." (Nurse 2, 15 years)
	Physician	"Simulation-based robotic training was highly engaging; performance scores promoted competitiveness and enabled monitoring of skill progression." (Physician 4, 4 years)
	Physician	"Practice using animal models that closely simulated clinical conditions was particularly informative." (Physician 9, 20 years)
Reflective observation	Nurse	"Careful attention to patient positioning and docking site selection improved surgical safety." (Nurse 2, 15 years)
	Nurse	"Without this training, assisting in live surgery would have been difficult. Previously unfamiliar aspects became clearer, increasing confidence." (Nurse 14, 3 years)
	Physician	"Firsthand experience of differences from existing robot system significantly reduced the burden of adapting to the new system." (Physician 5, 10 years)
	Physician	"Prior training on robotic arm and camera collisions, out-of-range scenarios, and their management enabled calm intraoperative responses." (Physician 8, 3 years)
Abstract conceptualization	Nurse	"Improved understanding of the robotic system enabled a transition from passive participation to active contribution." (Nurse 7, 2 years)
	Nurse	"Training enhanced understanding of SP robotic principles and enabled anticipation of potential intraoperative challenges." (Nurse 5, 7 years)
	Physician	"Understanding the ^a CRC highlighted the importance of precise alignment." (Physician 8, 3 years)
	Physician	"The training clarified that the CRC in SP system is larger and allows a wider range of motion than that in Xi systems, making precise alignment critical." (Physician 8, 3 years)
	Nurse	"When instrument insertion was challenging, applying techniques learned during training enabled relatively easy insertion." (Nurse 21, 4 years)
	Nurse	"During surgery, joint training facilitated a smooth workflow and enhanced collaborative problem-solving." (Nurse 1, 10 years)
	Physician	"Training transformed previously vague concepts into concrete understanding, supporting adaptation from MP to SP surgery." (Physician 5, 10 years)
	Physician	"Direct system operation and exposure to real problems rather than passive instruction made learning memorable and readily applicable in clinical procedures." (Physician 8, 3 years)
Outside framework	Physician	"Given prior extensive experience in robotic surgery, the training served primarily as a refresher rather than a significant learning experience." (Physician 11, 10 years)
	Physician	"Overconfidence from extensive multi-port experience hindered learning." (Physician 5, 10 years)

^aCRC, custom remote center; MP, multi-port; SP, single-port

However, physicians with extensive MP experience report limited engagement, suggesting that Kolb's experiential cycle is potentially most applicable when learners encounter sufficient novelty. This is consistent with adult learning theory, suggesting that prior knowledge both facilitates and constrains new learning [19]. One physician identified "overconfidence from extensive MP experience" as a barrier, and logistical factors emerged as contextual influences independent of the experiential cycle. Studies report similar findings in robotic surgery education [17, 18]. Collectively, Kolb's framework is most applicable when training is transformative rather than incremental.

Synergistic effects of profession-specific expertise

Profession-specific learning emphases emerged in response to structural constraints of the SP system. Nurses highlighted

workflow coordination, docking precision, and bedside workspace management—collectively conceptualized as "surgical space management." This finding is consistent with those of qualitative studies showing that perioperative nurses in robotic surgery develop anticipatory coordination and troubleshooting capabilities [27, 35]. It also aligns with studies showing role expansion beyond traditional perioperative functions, with skills often acquired through informal, practice-based learning rather than structured curricula [26, 27].

In contrast, physicians emphasized adaptation to SP-specific technical demands, including triangulation within the single-cannula workspace, instrument collision avoidance, and recalibration of force feedback. These findings are consistent with those of simulation-based studies showing that MP skills do not readily transfer to SP platforms [13].

With increasing system knowledge, nurses reported a shift from peripheral to more active engagement, consistent with situated learning theory [36] and findings that trained robotic surgery nurses exhibit faster adaptation and greater innovativeness [30].

Design principles for robotic surgery education

Participant accounts suggest several practical implications as context-sensitive recommendations for single-site SP training.

First, transition-focused curricula targeting SP-specific “gap areas” among experienced MP users were most effective when highlighting novel system constraints rather than generic robotic fundamentals. This is consistent with previously proposed competency-stratified curricula [37]. The phased training pathway used in this study may serve as a template for similar platform transitions.

Second, immediate feedback facilitated rapid correction of MP-derived habits, consistent with models emphasizing timely coaching [38].

Third, joint training enlightened surgeons about bedside constraints and enabled nurses to anticipate intraoperative needs, consistent with evidence that team training enhances workflow efficiency [14, 15] and systematic reviews highlighting the need for team-based interventions in robotic-assisted surgery [16].

Fourth, limited learning gain reported by some experienced physicians suggests that transition curricula may benefit from differentiated, experience-based pathways, including abbreviated foundational modules and extended advanced application sessions for experienced practitioners.

Limitations

This study has some limitations.

First, this single-institution study was conducted at a high-volume tertiary center with established Xi-based practice, potentially limiting the generalizability of the findings. Institutions with differing surgical volumes, baseline robotic experience, or organizational cultures may exhibit different learning trajectories. Additionally, the homogeneous context—shared protocols, a consistent training team, and a single specialty—further constrains transferability. Second, reliance on self-reported data reflects perceived rather than objectively measured skills; therefore, readiness and confidence should be interpreted as subjective improvements. Third, the cross-sectional design precluded assessment of long-term retention. Fourth, subsequent mentorship stages (TR-200 to TR-500) were not captured in this study. Fifth, the use of written questionnaires, rather than face-to-face interviews, may have limited response depth by precluding

real-time probing and follow-up. This approach was adopted to reduce social desirability bias in a hierarchical clinical setting and accommodate clinical scheduling constraints; nevertheless, future studies could use semi-structured interviews to generate richer qualitative data. Sixth, demographic data were limited to sex and years of clinical experience, as the questionnaires were originally designed for educational quality assurance rather than research purposes. The lack of data on professional level, subspecialty, prior MP experience, and SP exposure limits the interpretation of between-participant differences. Seventh, translation of responses from Korean to English may introduce interpretative bias. Although a structured dual-reviewer consensus process was applied, a formal back-translation procedure was not conducted, potentially limiting the verification of semantic equivalence. Eighth, as most participants had prior MP experience, the findings may not reflect the learning trajectories of novice users.

Conclusions

Hands-on exposure to SP-specific spatial constraints, combined with structured reflection, facilitated reorganization of established practices and increased perceived confidence. Nurses focused on workflow reliability, while physicians emphasized articulation control within confined operative fields. Both groups reported improved readiness and inter-professional coordination; however, experienced physicians reported limited learning gain, suggesting that prior expertise may moderate engagement.

As a single-institution study based on self-reported perceptions, these findings should be interpreted as preliminary insights. The phased training structure provides a curricular framework adaptable to other contexts, though further validation is required. Future research should include longitudinal studies of skill retention and clinical outcomes across the full training pathway (TR-200 to TR-500), multi-institutional comparisons of transition experiences, and objective performance metrics to determine whether perceived gains translate into measurable clinical improvements.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11701-026-03484-5>.

Acknowledgements We thank Chung-Ang University Hospital for supporting this study and all healthcare professionals who shared their insights and experiences. We also acknowledge Seokjin Yoon (Intuitive Surgical Korea, Inc.) for his support during the training program.

Author contributions Conceptualization: Young Gyu Kwon, Se Young Choi, Hye Young Park, Yu Seob Shin, Chan Woong Kim; Data curation: Young Gyu Kwon, Hye Young Park; Formal analysis: Young Gyu Kwon, Se Young Choi, Chan Woong Kim; Investigation: Young

Gyu Kwon, Hye Young Park, Chan Woong Kim; Methodology: Young Gyu Kwon, Se Young Choi, Yu Seob Shin, Chan Woong Kim; Project administration: Chan Woong Kim; Software: Young Gyu Kwon; Supervision: Chan Woong Kim; Validation: Se Young Choi, Chan Woong Kim; Visualization: Young Gyu Kwon. Writing – original draft preparation: Young Gyu Kwon, Se Young Choi; Writing – review and editing: Young Gyu Kwon, Se Young Choi, Chan Woong Kim.

Funding Open Access funding enabled and organized by Chung-Ang University Hospital. The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Data availability The data that support the findings of this study are not openly available due to ethical constraints and are available from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare no competing interests.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Institutional Review Board of Chung-Ang University Hospital (IRB No. 2602-014-675).

Consent to participate The requirement for individual informed consent to participate was waived by the Institutional Review Board because the data were originally collected as part of a routine educational quality assurance process and were analyzed retrospectively in de-identified form.

Consent to publish Not applicable, as this study contains no identifiable individual data, including personal details, images, or videos; all participant responses were de-identified and reported using anonymized codes.

Open Access This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

References

- George EI, Brand TC, LaPorta A, Marescaux J, Satava RM (2018) Origins of robotic surgery: from skepticism to standard of care. *JSLs* 22. <https://doi.org/10.4293/JSLs.2018.00039>. e2018.00039
- Basile G, Gallioli A, Diana P et al (2024) Current standards for training in robot-assisted surgery and endourology: a systematic review. *Eur Urol* 86:130–145. <https://doi.org/10.1016/j.eururo.2024.04.008>
- Seo IY (2015) Urologic robotic surgery in Korea: past and present. *Korean J Urol* 56:546–552. <https://doi.org/10.4111/kju.2015.56.8.546>
- Katsimperi S, Tzelvels L, Feretzakis G et al (2025) Single-port vs. multi-port robotic surgery in urologic oncology: a comparative analysis of current evidence and future directions. *Cancers (Basel)* 17:2847. <https://doi.org/10.3390/cancers17172847>
- Cianci S, Rosati A, Rumolo V et al (2019) Robotic single-port platform in general, urologic, and gynecologic surgeries: a systematic review of the literature and meta-analysis. *World J Surg* 43:2401–2419. <https://doi.org/10.1007/s00268-019-05049-0>
- Samarasekera D, Kaouk JH (2014) Robotic single port surgery: current status and future considerations. *Indian J Urol* 30:326–332. <https://doi.org/10.4103/0970-1591.128504>
- Nguyen TT, Basilius J, Ali SN, Dobbs RW, Lee DI (2023) Single-port robotic applications in urology. *J Endourol* 37:688–699. <https://doi.org/10.1089/end.2022.0600>
- Sinha R, Sanjay M, Rupa B, Kumari S (2015) Robotic surgery in gynecology. *J Minim Access Surg* 11:50–59. <https://doi.org/10.4103/0972-9941.147690>
- Volpe A, Ahmed K, Dasgupta P et al (2015) Pilot validation study of the European Association of Urology robotic training curriculum. *Eur Urol* 68:292–299. <https://doi.org/10.1016/j.eururo.2014.10.025>
- Chitwood WR Jr, Nifong LW, Chapman WH et al (2001) Robotic surgical training in an academic institution. *Ann Surg* 234:475–484. <https://doi.org/10.1097/0000658-200110000-00007>
- Chen R, Rodrigues Armijo P, Krause C, Siu KC, Olenikov D (2020) A comprehensive review of robotic surgery curriculum and training for residents, fellows, and postgraduate surgical education. *Surg Endosc* 34:361–367. <https://doi.org/10.1007/s00464-019-06775-1>
- Lenfant L, Corrigan D, Beksac AT, Schwen Z, Kaouk J (2021) Learning curve analysis of single-port robot-assisted extraperitoneal prostatectomy using the cumulative sum (CUSUM) method. *BJU Int* 128:688–691. <https://doi.org/10.1111/bju.15588>
- Ghazi A, Schuler N, Saba P et al (2023) Do skills naturally transfer between multiport and single-port robotic platforms? a comparative study in a simulated environment. *J Endourol* 37:233–239. <https://doi.org/10.1089/end.2022.0467>
- Vigo F, Egg R, Schoetza A et al (2022) An interdisciplinary team-training protocol for robotic gynecologic surgery improves operating time and costs: analysis of a 4-year experience in a university hospital setting. *J Robot Surg* 16:89–96. <https://doi.org/10.1007/s11701-021-01209-4>
- Cohen TN, Anger JT, Kanji FF et al (2022) A novel approach for engagement in team training in high-technology surgery: the robotic-assisted surgery Olympics. *J Patient Saf* 18:570–577. <https://doi.org/10.1097/PTS.0000000000001056>
- Kanji F, Catchpole K, Choi E et al (2021) Work-system interventions in robotic-assisted surgery: a systematic review exploring the gap between challenges and solutions. *Surg Endosc* 35:1976–1989. <https://doi.org/10.1007/s00464-020-08231-x>
- Turner SR, Mormando J, Park BJ, Huang J (2020) Attitudes of robotic surgery educators and learners: challenges, advantages, tips and tricks of teaching and learning robotic surgery. *J Robotic Surg* 14:455–461. <https://doi.org/10.1007/s11701-019-01013-1>
- Shaw RD, Eid MA, Bleicher J et al (2022) Current barriers in robotic surgery training for general surgery residents. *J Surg Educ* 79:606–613. <https://doi.org/10.1016/j.jsurg.2021.11.005>
- Kolb DA (2014) *Experiential learning: experience as the source of learning and development*, 2nd edn. Pearson Education, Upper Saddle River
- Wijnen-Meijer M, Brandhuber T, Schneider A, Berberat PO (2022) Implementing Kolb's experiential learning cycle by linking real experience, case-based discussion and simulation. *J Med*

- Educ Curric Dev 9:23821205221091511. <https://doi.org/10.1177/23821205221091511>
21. Kneebone R (2005) Evaluating clinical simulations for learning procedural skills: a theory-based approach. *Acad Med* 80:549–553. <https://doi.org/10.1097/00001888-200506000-00006>
 22. Porterfield JR Jr, Podolsky D, Ballecer C et al (2024) Structured resident training in robotic surgery: recommendations of the robotic surgery education working group. *J Surg Educ* 81:9–16. <https://doi.org/10.1016/j.jsurg.2023.09.006>
 23. Hays SB, Rojas AE, Kuchta K et al (2024) How to integrate robotic training in surgical residency? an example of a 2-week robotic rotation. *J Robot Surg* 18:225. <https://doi.org/10.1007/s11701-024-01977-9>
 24. Moloney R, Coffey A, Coffey JC, Brien BO (2023) Nurses' perceptions and experiences of robotic assisted surgery (RAS): an integrative review. *Nurse Educ Pract* 71:103724. <https://doi.org/10.1016/j.nepr.2023.103724>
 25. Möller L, Olsen RG, Jørgensen L et al (2024) Training and education of operating room nurses in robot-assisted surgery: a systematic review. *Surg Endosc* 38:7024–7036. <https://doi.org/10.1007/s00464-024-11335-3>
 26. Kang MJ, De Gagne JC, Kang HS (2016) Perioperative nurses' work experience with robotic surgery: a focus group study. *Comput Inf Nurs* 34:152–158. <https://doi.org/10.1097/CIN.0000000000000224>
 27. Uslu Y, Altınbaş Y, Özercan T, van Giersbergen MY (2019) The process of nurse adaptation to robotic surgery: a qualitative study. *Int J Med Robot* 15:e1996. <https://doi.org/10.1002/rcs.1996>
 28. Sandelowski M (2000) Whatever happened to qualitative description? *Res Nurs Health* 23:334–340. [https://doi.org/10.1002/1098-240X\(200008\)23:4<334::AID-NUR9>3.0.CO;2-G](https://doi.org/10.1002/1098-240X(200008)23:4<334::AID-NUR9>3.0.CO;2-G)
 29. Neergaard MA, Olesen F, Andersen RS, Sondergaard J (2009) Qualitative description—the poor cousin of health research? *BMC Med Res Methodol* 9:52. <https://doi.org/10.1186/1471-2288-9-52>
 30. Silveira Thomas Porto C, Catal E (2021) A comparative study of the opinions, experiences and individual innovativeness characteristics of operating room nurses on robotic surgery. *J Adv Nurs* 77:4755–4767. <https://doi.org/10.1111/jan.15020>
 31. Braun V, Clarke V, Boulton E, Davey L, McEvoy C (2021) The online survey as a qualitative research tool. *Int J Soc Res Methodol* 24:641–654. <https://doi.org/10.1080/13645579.2020.1805550>
 32. Dillman DA, Smyth JD, Christian LM (2014) Internet, phone, mail, and mixed-mode surveys: the tailored design method, 4th edn. Wiley, Hoboken
 33. Braun V, Clarke V (2006) Using thematic analysis in psychology. *Qual Res Psychol* 3:77–101. <https://doi.org/10.1191/1478088706qp0630a>
 34. Lincoln YS, Guba EG, Oaks T (1985) 289–331. [https://doi.org/10.1016/0147-1767\(85\)90062-8](https://doi.org/10.1016/0147-1767(85)90062-8)
 35. Senol Çelik S, Ozdemir Koken Z, Canda AE, Esen T (2023) Experiences of perioperative nurses with robotic-assisted surgery: a systematic review of qualitative studies. *J Robot Surg* 17:785–795. <https://doi.org/10.1007/s11701-022-01511-9>
 36. Lave J, Wenger E (1991) Situated learning: legitimate peripheral participation. Cambridge University Press, Cambridge. <https://doi.org/10.1017/CBO9780511815355>
 37. Ahmed K, Khan R, Motttrie A et al (2015) Development of a standardised training curriculum for robotic surgery: a consensus statement from an international multidisciplinary group of experts. *BJU Int* 116:93–101. <https://doi.org/10.1111/bju.12974>
 38. Ahlering TE, Skarecky D, Lee D, Clayman RV (2003) Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. *J Urol* 170:1738–1741. <https://doi.org/10.1097/01.ju.0000092881.24608.5e>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.