



University of Southern Denmark

## Identifying curriculum content for a cross-specialty robotic-assisted surgery training program a Delphi study

Hertz, Peter; Houliind, Kim; Jepsen, Jan; Bundgaard, Lars; Jensen, Pernille; Friis, Mikkel;  
Konge, Lars; Bjerrum, Flemming

*Published in:*  
Surgical Endoscopy

*DOI:*  
10.1007/s00464-021-08821-3

*Publication date:*  
2022

*Document version:*  
Accepted manuscript

### *Citation for pulished version (APA):*

Hertz, P., Houliind, K., Jepsen, J., Bundgaard, L., Jensen, P., Friis, M., Konge, L., & Bjerrum, F. (2022).  
Identifying curriculum content for a cross-specialty robotic-assisted surgery training program: a Delphi study.  
*Surgical Endoscopy*, 36, 4786-4794. <https://doi.org/10.1007/s00464-021-08821-3>

Go to publication entry in University of Southern Denmark's Research Portal

### **Terms of use**

This work is brought to you by the University of Southern Denmark.  
Unless otherwise specified it has been shared according to the terms for self-archiving.  
If no other license is stated, these terms apply:

- You may download this work for personal use only.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying this open access version

If you believe that this document breaches copyright please contact us providing details and we will investigate your claim.  
Please direct all enquiries to [puresupport@bib.sdu.dk](mailto:puresupport@bib.sdu.dk)

## Title Page

**Title:** Identifying curriculum content for a cross-specialty robotic-assisted surgery training program – A Delphi study

**Running head:** Cross-specialty curriculum for RAS

**Authors (in order):** Peter Hertz, MD (1,2), Kim Houliind, PhD (3,2), Jan Jepsen, MD (4,10), Lars Bundgaard, MD (5), Pernille Jensen, PhD (6,7), Mikkel Friis, MD (8), Lars Konge, PhD (10,11), Flemming Bjerrum, PhD (9,10).

### **Affiliations:**

1. Department of Surgery, Hospital Lillebaelt, University of Southern Denmark, Kolding, Denmark.
2. Department of Regional Health Research, University of Southern Denmark, Kolding, Denmark.
3. Department of Vascular Surgery, Hospital Lillebaelt, University of Southern Denmark, Denmark.
4. Department of Urology, Herlev-Gentofte Hospital, Copenhagen University Hospital, Denmark.
5. Department of Surgery, Hospital Lillebaelt, University of Southern Denmark, Vejle, Denmark.
6. Department of Gynecology, Aarhus University Hospital and Faculty of Health, Institute of Clinical Medicine, Aarhus University, Denmark.
7. Faculty of Health Sciences, Department of Clinical Research, University of Southern Denmark, Odense C, Denmark
8. Department of Skills Training and Simulation, NordSim, Aalborg University Hospital, Denmark
9. Department of Surgery, Rigshospitalet, Copenhagen University Hospital, Denmark.
10. Copenhagen Academy for Medical Education and Simulation (CAMES), Center for HR and Education, The Capital Region of Denmark.
11. University of Copenhagen, Denmark.

### **Corresponding author and contact person for data or reprints requests:**

Peter Hertz

Department of Surgery

Hospital Lillebaelt, Kolding

University of Southern Denmark

Denmark

Sygehusvej 24

6000 Kolding

[Peter.hertz@rsyd.dk](mailto:Peter.hertz@rsyd.dk)

Telephone +45 76362000

**Funding:**

This study is part of a Ph.D. project funded by the University of Southern Denmark (Faculty scholarship for Peter Hertz). The funder did not influence the protocol development or had access to the data.

## ABSTRACT

**Background:** Robotic-assisted surgery is increasing and there is a need for a structured and evidence-based curriculum to learn basic robotic competencies. Relevant training tasks, eligible trainees, realistic learning goals, and suitable training methods must be identified. We sought to develop a common curriculum that can ensure basic competencies across specialties.

**Methods:** Two robotic surgeons from all departments in Denmark conducting robotic-assisted surgery within gynecology, urology, and gastro-intestinal surgery, were invited to participate in a three-round Delphi study to identify learning goals and rank them according to relevance for a basic curriculum. An additional survey was conducted after the Delphi rounds on what training methods were considered best for each learning goal and who (console surgeon/patient-side assistant) should master each learning goal.

**Results:** Fifty-six robotic surgeons participated and the response rates were 86%, 89%, and 77%, for rounds 1, 2 and 3, respectively. The Delphi study identified 40 potential learning goals, of which 29 were ranked as essential e.g. *Understand the link between arm placement and freedom of movement* or *Be able to perform emergency un-docking*. In the additional survey, the response rate was 70%. Twenty-two (55%) of the identified learning goals were found relevant for the patient-side assistant and twenty-four (60%) were linked to a specific suitable learning method with >75% agreement.

**Conclusions:** Our findings can help training centers plan their training programs concerning educational content and methods for training/learning. Furthermore, patient-side assistants should also receive basic skills training in robotic surgery.

**Keywords:** Cross-specialty, robotic surgery, curriculum development, education.

## INTRODUCTION

Robotic-assisted surgery is increasingly being used in most surgical specialties and the leading producer of robotic systems reported a number of 1,229,000 conducted procedures worldwide using their systems in 2019 [1].

There is a learning curve for new surgeons as the handling of the instruments, visualization and haptic feedback in robotic surgery is different from conventional laparoscopy [2–4]. Furthermore, the inclusion of a robot to the team adds further complexity to surgery and increases demands on the operating team [5].

Surgical errors often occur due to lack of competence or communication breakdowns [6] and this also applies for robotic-assisted surgery [7]. Some errors are specific for robotic surgery and therefore additional education is important to ensure that robotic-assisted surgeries are performed safely [8].

An international multidisciplinary consensus group statement on robotic surgery recommended a structured training program for novices in robotic-assisted surgery [9].

Currently, the education offered to robotic surgeons varies in content and design [10–12] and the quality of training differs depending on the location and specialty [13]. The content of the training programs is often specialty-dependent and lacks a structured methodology. A full surgical curriculum should include relevant theoretical, technical, and non-technical skills.

Robotic-assisted surgery is widely used in gynecology, urology, and gastro-intestinal surgery and there are many common basic skills and competencies, e.g. knowledge of robotic equipment or emergency procedures. In a nationwide questionnaire among robotic surgeons from the three specialties in the Netherlands, the majority agreed on the need for a multidisciplinary basic training

program for robotic surgery [14]. There is currently no cross-specialty consensus regarding the content or form of a common robotic curriculum.

Curriculum development is resource-efficient when overlaps and gaps of the learning goals are identified [15]. According to *Kern's approach to curriculum development* [16, 17], six steps should be included.

Where Kern's step 1 is problem identification and is described above, Kern's steps 5 and 6 are implementation and evaluation, these are often determined locally by the politics, funds, and support of each educational center.

This study aimed to identify who should master relevant learning goals in regard to their role in the surgical team (Kern's step 2). And to identify learning goals and establish consensus on the rank of relevance for basic competencies for robotic-assisted surgery across the three specialties: gynecology, urology, and gastro-intestinal surgery (Kern's step 3). And finally, to identify suitable learning methods for each identified learning goal (Kern's step 4).

## **METHODS**

We used a three-rounded Delphi survey to identify and rank the importance of the learning goals. This method has previously been used to reach consensus on content for curricula in medical education [2, 18–21].

The Delphi method is used to systematically gather opinions and to rank these through an iterative process. In the first round, participants can suggest educational content, which then will be synthesized and rated in the second round. In the third round, the Delphi panelists are presented with the anonymized responses from the previous round and have the chance to re-evaluate their previous responses [22].

After the Delphi survey, we asked the Delphi participants which training methods should be used and who in the surgical team (console surgeon/patient-side assistant) should master each identified learning goal.

### *Selection of participants for the Delphi panel*

#### **Processing group:**

A Delphi processing group consisting of seven members was formed. The composition of the group included experienced surgeons performing robotic-assisted surgery from each of the three above-mentioned specialties, and with geographically dispersed work locations representing the different regions of Denmark. The group also included surgeons with an interest or background in medical education research. The members were identified and invited based on these roles.



The Delphi panel:

All departments of gynecology, urology, and gastrointestinal surgery in Denmark performing robotic-assisted surgery were identified. Two robotic surgeons from each department were invited to participate in the survey, which evens out the possible differences in behavior and attitudes that may exist among departments. The participants were appointed either by the head of the department or by the regional representative from the processing group. In total, 56 robotic surgeons from 28 departments were invited to participate in the Delphi panel. The distribution of participants was: Gynecology n=18, Urology n=16, Gastro-intestinal surgery n=22.

#### *Questionnaire design and distribution*

The questionnaire was designed and distributed through the online survey software Surveyxact© (Rambøll Management Consulting, Aarhus, Denmark.) The questionnaire was pilot tested on surgeons who were not included in the Delphi panel to ensure an appropriate understanding of the questions.

All questionnaires were written in English and the participants had the opportunity to respond in English or Danish. The processing group then translated the Danish answers into English during the synthesis of learning goals. The Delphi participants had three weeks to answer each questionnaire except for the second Delphi round which had an extra week added due to national holidays.

Weekly reminder e-mails were sent to participants who had not yet replied.

#### *The Delphi Process*

The Delphi participants had to provide written informed consent and information on their experience as robotic surgeons before they could participate in the first round of the survey.

### Round 1:

In round 1, the Delphi panel was presented with an open-ended question: “*What content do you think should be included in a robotic-assisted surgery curriculum.*” The participants had the opportunity to suggest educational content and add comments if they felt there was a need for elaboration.

The submissions from the first round were summarized in a single document, listed in random order for anonymizing purpose, and distributed to the processing group prior to the first process group meeting. At the meeting, duplicates were removed, understandings were discussed and resolved, and irrelevant or procedure-specific items were excluded. Thus synthesizing a list of proposed learning goals that were formulated in accordance with Bloom's taxonomy for curriculum development [23]. The identified learning goals were indexed in domains generated by the processing group.

### Round 2:

In the second round, the synthesized list of learning goals was presented to the participants who were asked to rate them for relevance for a robotic-assisted surgery curriculum on a five-point

Likert scale:

1 = not relevant, 2 = less relevant, 3 = relevant, 4 = very relevant, 5 = essential.

The participants were encouraged to comment and suggest new learning goals to each domain in case they considered the list to be incomplete.

In the processing of round 2, the new submissions of learning goals and comments were presented to the processing group after the same framework used to process round 1 and new learning goals

were synthesized. The participants' rating data was analyzed and displayed as bar charts displaying the distribution of responses presented as percentages on the 1-5 Likert scale. None of the rated learning goals was excluded in the processing of round 2.

Round 3:

We presented the rating results as bar charts with the distribution of responses for each of the learning goals from round 2 for the participants. The participants rated the learning goals and could not comment or add new learning goals in this round. None of the rated learning goals were excluded in the processing of round 3.

Additional survey:

After the final Delphi round, we asked the participants who should master each learning goal: Console Surgeons, Patient-side assistants, or both. In addition, they were asked to choose suitable learning methods for each learning goal from a list (Table 1). The participants could select more than one learning method per learning goal.

A flowchart of the Delphi process is illustrated in Figure 1.

The responses of the participants were anonymous throughout the study.

#### *Definition on consensus, ranking, and data analysis*

The rank of learning goals was determined in regard to the strength of the agreement using the measures; median, interquartile range, and proportion of the panel responding 4 or 5 on the Likert scale in different combinations to evaluate the criteria of *essential*, *very relevant*, *relevant*, or *not*

*relevant* (Table 2). These criteria have been used previously in a similar consensus study [24]. Data were analyzed using SPSS V.24. (IBM Inc., Armonk, New York, USA).

#### *Ethical approval*

The study was submitted to the Regional Ethical Committee of Southern Denmark, which found that ethical approval was not required (Journal No. 201920000-88).

## RESULTS

The response rates were 86%, 89%, and 77% in the first, second, and third rounds, respectively. All 28 departments were represented in all three Delphi rounds. The distribution of responses according to specialty for each round is displayed in Table 3.

The median (range) years of experience of practicing robotic surgery among the participants who responded in the first round were 4 years (1-12 years).

In the first round, the participants supplied 227 item suggestions. After the removal of duplicates and understandings were resolved, 37 learning goals were synthesized and indexed in domains as listed in Table 4. In the second round, the participants supplied six new suggestions for learning goals and added 22 comments. After processing, three new learning goals were added and two learning goals were rephrased for clarification, resulting in a total of 40 learning goals. The rating results from rounds 2 and 3 are submitted as a table in supplementary materials.

In the final Delphi round the participants rated 35 of the 40 potential identified learning goals as relevant or higher, and five learning goals as *not relevant*. Six learning goals rated in round 2 changed their rank after re-rating in round 3. Twenty-nine of the learning goals were rated essential to be included in a curriculum. All the identified learning goals in the domain *technical skills* were rated essential and there was an overall tendency that technical skills were rated higher than learning goals labeled knowledge. One example is the goal: “*Be able to perform intra-abdominal entry technique*” which was rated essential while the learning goal “*Knowledge of physiology of pneumoperitoneum*” reached consensus as being *Not relevant*. Results from both rounds 2 and 3 are displayed in the supplementary materials and the final consensus results are shown in Table 5.

In the additional survey on training methods, 39 (70%) of the 56 participants responded. Twenty-seven departments were represented as one urology department did not respond (Table 3). For 24 of

the learning goals, there was an agreement of >75% on a specific suitable learning/training method. In general, E-learning was rated high for the theoretical learning goals and virtual reality and animal models were rated high for the technical learning goals. There was >75% agreement on 22 (55%) learning goals to be trained by both the console surgeon and the patient-side assistant. In table 5, the responses are displayed as a proportion of the responding participants' voting for each learning goal.

## DISCUSSION

We identified 35 relevant learning goals for basic competencies in robotic-assisted surgery across three specialties. We obtained a very high response rate compared with other studies [25, 26] as a higher number of items is normally associated with a lower response rate [27]. Additionally, we identified which training/learning methods robotic surgeons consider best for each of the competencies and whether the console surgeons, the patient-side assistants, or both should acquire the competencies. Our findings can work as the first blueprint for developing curricula for basic competencies in robotic-assisted surgery across specialties.

A surgical curriculum should cover both theoretical, technical, and non-technical skills [13]. We found that *E-learning* is preferred for the theoretical knowledge, *Virtual Reality* and *Animal models* for the technical skills training, and *Team Training* for the non-technical skills. This is in line with previously published single-specialty curricula [28, 29] stating that a curriculum must include various teaching methods depending on the learning goal.

There was a tendency that skills were rated more relevant than knowledge. The same was observed when Ismail et al. explored core skills for robotic first assistants in gynecology [30] and when Thellesen et al. explored curriculum content for Cardiotocography [25]. Another example is the item *Understand the aspects and benefits of the pre-procedural checks* which reached consensus as *Not relevant* despite its proven justification for surgical procedures in general [31]. Currently, many robotic surgeons have experience from conventional laparoscopy and open surgery and the Delphi participants may consider the learning goals focusing on knowledge as basic surgical competencies, which trainees should already be familiar with before commencing robotic-assisted surgery training. As the use of robotic-assisted surgery continues to grow and with work hour regulations there is a potential risk of trainees having less experience in conventional surgery skills when they are

introduced to robotic surgery [32]. Hence, it is likely necessary to teach skills that used to be mastered before learning robotic-assisted surgery alongside specific robotic skills. Educational institutions should pay attention to this in the future.

In the domain *Non-technical skills*, five learning goals were identified and only two were rated essential. Non-technical skills often do not receive the same degree of interest and attention as technical skills [32]. Ahmed et al. describe the inclusion and importance of non-technical skills when establishing a standardized curriculum for robotic surgeons [33], whereas Ismail et al. did not identify any non-technical skills [30]. In a study including the entire surgical team, Al-Jundi et al. reported that 81% of the participants stated that non-technical skills are as important as technical skills in improving the surgical outcome [34]. The Delphi panel was composed of surgeons alone, and this may be one of the reasons for the low attention to non-technical skills. One other explanation for the low attention to non-technical learning goals in our study could be that they are considered integrated into the identified technical learning goals [35]. The learning goal *Be able to perform emergency un-docking* which is technical but contains non-technical aspects e.g. decision-making, communication, leadership, and situational awareness is an example of this inter-connection. This is consistent with the findings of Raison et al. when identifying suitable components for the evaluation of non-technical skills in robotic surgery [36].

As an important measure of Kern's framework [16], we surveyed opinions on which learning goals were relevant for the console surgeons and the patient-side assistants, respectively. For 22 (55%) of the learning goals, at least 75% of participants thought they were relevant for the patient-side assistant as well as the console surgeon. The 75% agreement is a common definition of consensus [37]. In the domain *Technical skills*, the Delphi panel was divided; more than half of the panel voted four of the seven learning goals as only being relevant for the console surgeon, thus implying that the identified technical skills were not relevant for the assistant. In comparison, Ismail et al.



identified many technical skills of relevance for the first assistant only [30]. In the future, surgical trainees are more likely to be exposed to robotic surgery during their training [38] and the patient-side assistant in robotic surgery has more responsibility than an assistant during conventional surgery [39]. Further studies are needed to explore what educational content the patient-side assistant needs. Our findings indicate that patient-side assistants should be invited to participate in the basic skills part of a robotic-assisted surgery curriculum [32].

Educational strategies is step four in Kern's framework [16] and our study differs from the previous studies not only by exploring cross-specialty learning goals but also by establishing consensus on their rank of relevance and identifying which learning methods are suitable for each learning goal. By including three specialties, we identified common basic surgical non-technical and technical skill competencies. The level of agreement among the participants and the fact that the list of learning goals is similar to other single-specialty studies [30, 33, 40], support the concept of using the same basic curriculum for multiple specialties. The participants' experience in robotic surgery varied from one to 12 years. This allowed us to gather opinions from new and well-established robotic surgeons. Often Delphi panels consist of decision-makers or participants who are very experienced in their field [2, 12, 25]. However, we believe that the range of experience among participants is a strength as the focus of this study was identification of basic skills and junior robotic surgeons may have a different perception of the competencies required than senior surgeons. Including participants at different experience levels have been used in earlier studies [18, 41].

A possible limitation is that we only included robotic surgeons employed in Denmark. With reference to the mentioned differences among educational centers, we believe that our results can be applied internationally because the competencies required are the same.

We ranked our learning goals instead of reaching consensus on the final content for a future curriculum. There are regional differences in needs, resources, and educational traditions that must be considered when developing and implementing a curriculum. Our findings can act as a blueprint for the design of training programs for basic robotic competencies, as both relevance of the learning goals and preferred training methods can help design a curriculum. As an example, in the domain *technical skills*, the teaching method Live animals/animal models was rated highest for all learning goals. Using live animals for basic skills training is not accessible everywhere and virtual reality simulation also received a high rating and may be a viable alternative.

The learning goals identified as relevant in this study can be used to develop basic robotic surgery curricula. We explored opinions on suitable methods to master each learning goal, which can guide educational centers in implementing cross-specialty training programs. The majority of the learning goals identified for the console surgeons were found relevant for the patient-side assistants and basic skills training in robotic surgery for patient-side assistants should be considered.

**Acknowledgments:**

We would like to thank all the participants in the Delphi panel, their departments and hospitals: Rigshospitalet (Copenhagen), Herlev Hospital, University Hospital Zealand; Køge and Roskilde, Aalborg University Hospital, Aarhus University Hospital, Region Hospital Herning, Region Hospital Holstebro, Odense University Hospital, Hospital Sønderjylland, Lillebaelt Hospital, and Hospital of South West Jutland.

**Data sharing statement:**

The datasets used for this study are available from the corresponding author on reasonable request.

**Disclosure statements:**

Drs. Peter Hertz, Flemming Bjerrum, Kim Houliind, Pernille Tine Jensen, Mikkel Lønborg Friis, Jan Jepsen, Lars Bundgaard and Lars Konge have no conflicts of interest or financial ties to disclose.

**References:**

1. Intuitive Surgical Announces Preliminary Fourth Quarter and Full Year 2019 Results.  
<https://isrg.intuitive.com/news-releases/news-release-details/intuitive-announces-preliminary-fourth-quarter-and-full-year>. Accessed 16 Nov 2020
2. Veronesi G, Dorn P, Dunning J, Cardillo G, Schmid RA, Collins J, Baste JM, Limmer S, Shahin GMM, Egberts JH, Pardolesi A, Meacci E, Stamenkovic S, Casali G, Rueckert JC, Taurchini M, Santelmo N, Melfi F, Toker A (2018) Outcomes from the Delphi process of the Thoracic Robotic Curriculum Development Committee. *Eur J Cardiothorac Surg* 53:1173–1179 . <https://doi.org/10.1093/ejcts/ezx466>
3. Peters BS, Armijo PR, Krause C, Choudhury SA, Oleynikov D (2018) Review of emerging surgical robotic technology. *Surg Endosc* 32:1636–1655 . <https://doi.org/10.1007/s00464-018-6079-2>
4. Kowalewski KF, Schmidt MW, Proctor T, Pohl M, Wennberg E, Karadza E, Romero P, Kenngott HG, Müller-Stich BP, Nickel F (2018) Skills in minimally invasive and open surgery show limited transferability to robotic surgery: results from a prospective study. *Surg Endosc* 32:1656–1667 . <https://doi.org/10.1007/s00464-018-6109-0>
5. Gillespie BM, Gillespie J, Boorman RJ, Granqvist K, Stranne J, Erichsen-Andersson A (2020) The Impact of Robotic-Assisted Surgery on Team Performance: A Systematic Mixed Studies Review. *Hum Factors*. <https://doi.org/10.1177/0018720820928624>
6. Gawande AA, Zinner MJ, Studdert DM, Brennan TA (2003) Analysis of errors reported by surgeons at three teaching hospitals. *Surgery* 133:614–621 .  
<https://doi.org/10.1067/msy.2003.169>

7. Muaddi H, Hafid M El, Choi WJ, Lillie E, de Mestral C, Nathens A, Stukel TA, Karanicolas PJ (2020) Clinical Outcomes of Robotic Surgery Compared to Conventional Surgical Approaches (Laparoscopic or Open). *Ann Surg Publish Ah*:1–7 .  
<https://doi.org/10.1097/sla.0000000000003915>
8. Quality and Patient Safety Division (2013) Advisory on Robot-assisted surgery. In: *Commonw. Massachusetts Board Regist. Med.* <https://www.mass.gov/doc/march-2013-robot-assisted-surgery-advisory/download>
9. Herron DM, Marohn M, A. Advincula, Aggarwal S, Palese M, Broderick T, Broeders I, Byer A, Curet M, Earle D, Giulianotti P, Grundfest W, Hashizume M, Kelley W, Lee D, Weinstein G, McDougall E, Meehan J, Melvin S, Menon M, Oleynikov D, Patel V, Satava R, Schwaitzberg S (2008) A consensus document on robotic surgery. *Surg Endosc Other Interv Tech* 22:313–325 . <https://doi.org/10.1007/s00464-007-9727-5>
10. ERUS Robotic Curriculum. In: *Eur. Assoc. Urol.* <https://uroweb.org/section/erus/education/>
11. Satava RM, Stefanidis D, Levy JS, Smith R, Martin JR, Monfared S, Timsina LR, Darzi AW, Moglia A, Brand TC, Dorin RP, Dumon KR, Francone TD, Georgiou E, Goh AC, Marcet JE, Martino MA, Sudan R, Vale J, Gallagher AG (2019) Proving the Effectiveness of the Fundamentals of Robotic Surgery (FRS) Skills Curriculum: A Single-blinded, Multispecialty, Multi-institutional Randomized Control Trial. *Ann Surg.*  
<https://doi.org/10.1097/sla.0000000000003220>
12. Stegemann AP, Ahmed K, Syed JR, Rehman S, Ghani K, Autorino R, Sharif M, Rao A, Shi Y, Wilding GE, Hassett JM, Chowriappa A, Kesavadas T, Peabody JO, Menon M, Kaouk J, Guru KA (2013) Fundamental skills of robotic surgery: A multi-institutional randomized controlled trial for validation of a simulation-based curriculum. *Urology* 81:767–774 .

<https://doi.org/10.1016/j.urology.2012.12.033>

13. Carpenter BT, Sundaram CP (2017) Training the next generation of surgeons in robotic surgery. *Robot Surg Res Rev* Volume 4:39–44 . <https://doi.org/10.2147/rsrr.s70552>
14. Brinkman W, de Angst I, Schreuder H, Schout B, Draaisma W, Verweij L, Hendriks A, van der Poel H (2017) Current training on the basics of robotic surgery in the Netherlands: Time for a multidisciplinary approach? *Surg Endosc* 31:281–287 . <https://doi.org/10.1007/s00464-016-4970-2>
15. Schreuder HW, Wolswijk R, Zweemer RP, Schijven MP, Verheijen RH (2012) Training and learning robotic surgery, time for a more structured approach: a systematic review. *Bjog* 119:137–149 . <https://doi.org/10.1111/j.1471-0528.2011.03139.x>
16. Thomas P A, Kern DE, Hughes MT CB (2015) Curriculum development for medical education: a six-step approach, Third Edit. Johns Hopkins University Press, Baltimore
17. Bjerrum F, Thomsen ASS (2018) Surgical simulation: Current practices and future perspectives for technical skills training. 40:668–675 .  
<https://doi.org/10.1080/0142159x.2018.1472754>
18. Topperzer MK, Thellessen L, Hoffmann M, Larsen HB, Weibel M, Lausen B, Schmiegelow K, Sørensen JL (2020) Establishment of consensus on content and learning objectives for an interprofessional education in childhood cancer: A Delphi survey. *BMJ Paediatr Open* 4: .  
<https://doi.org/10.1136/bmjpo-2019-000634>
19. Collins JW, Levy J, Stefanidis D, Gallagher A, Coleman M, Cecil T, Ericsson A, Mottrie A, Wiklund P, Ahmed K, Pratschke J, Casali G, Ghazi A, Gomez M, Hung A, Arnold A, Dunning J, Martino M, Vaz C, Friedman E, Baste JM, Bergamaschi R, Feins R, Earle D,

- Pusic M, Montgomery O, Pugh C, Satava RM (2019) Utilising the Delphi Process to Develop a Proficiency-based Progression Train-the-trainer Course for Robotic Surgery Training. *Eur Urol*. <https://doi.org/10.1016/j.eururo.2018.12.044>
20. Nayahangan LJ, Van Herzeele I, Konge L, Koncar I, Cieri E, Mansilha A, Debus S, Eiberg JP (2019) Achieving Consensus to Define Curricular Content for Simulation Based Education in Vascular Surgery: A Europe Wide Needs Assessment Initiative. *Eur J Vasc Endovasc Surg* 58:284–291 . <https://doi.org/10.1016/j.ejvs.2019.03.022>
21. Jensen RD, Paltved C, Jaensch C, Durup J, Beier-Holgersen R, Konge L, Nayahangan L, Madsen AH (2021) Identifying technical skills and clinical procedures in surgery for a simulation-based curriculum: a national general needs assessment. *Surg Endosc*. <https://doi.org/10.1007/s00464-020-08235-7>
22. Jones J, Hunter D (1995) Consensus methods for medical and health services research. *Bmj* 311:376–380 . <https://doi.org/10.1136/bmj.311.7001.376>
23. Khamis NN, Satava RM, Alnassar SA, Kern DE (2016) A stepwise model for simulation-based curriculum development for clinical skills, a modification of the six-step approach. *Surg Endosc* 30:279–287 . <https://doi.org/10.1007/s00464-015-4206-x>
24. Hackett S, Masson H, Phillips S (2006) Exploring consensus in practice with youth who are sexually abusive: Findings from a delphi study of practitioner views in the United Kingdom and the Republic of Ireland. *Child Maltreat* 11:146–156 . <https://doi.org/10.1177/1077559505285744>
25. Thellesen L, Hedegaard M, Bergholt T, Colov NP, Hoegh S, Sorensen JL (2015) Curriculum development for a national cardiocography education program: a Delphi survey to obtain

consensus on learning objectives. *Acta Obs Gynecol Scand* 94:869–877 .

<https://doi.org/10.1111/aogs.12662>

26. Thomsen ASS, la Cour M, Paltved C, Lindorff-Larsen KG, Nielsen BU, Konge L, Nayahangan LJ (2018) Consensus on procedures to include in a simulation-based curriculum in ophthalmology: a national Delphi study. *Acta Ophthalmol* 96:519–527 .  
<https://doi.org/10.1159/00049343110.1111/aos.13700>
27. Gargon E, Crew R, Burnside G, Williamson PR (2019) Higher number of items associated with significantly lower response rates in COS Delphi surveys. *J Clin Epidemiol* 108:110–120 . <https://doi.org/10.1016/j.jclinepi.2018.12.010>
28. Rusch P, Kimmig R, Lecuru F, Persson J, Ponce J, Degueldre M, Verheijen R (2018) The Society of European Robotic Gynaecological Surgery (SERGS) Pilot Curriculum for robot assisted gynecological surgery. *Arch Gynecol Obstet* 297:415–420 .  
<https://doi.org/10.1007/s00404-017-4612-5>
29. ERUS Robotic Curriculum. European Association of Urology.  
<https://uroweb.org/section/erus/education/>. Accessed 17 Nov 2020
30. Ismail A, Wood M, Ind T, Gul N, Moss E (2020) The development of a robotic gynaecological surgery training curriculum and results of a delphi study. *BMC Med Educ* 20:1–7 . <https://doi.org/10.1186/s12909-020-1979-y>
31. Haynes AB, Weiser TG, Berry WR, Lipsitz SR, Breizat A-HS, Dellinger EP, Herbosa T, Joseph S, Kibatala PL, Lapitan MCM, Merry AF, Moorthy K, Reznick RK, Taylor B, Gawande AA (2009) A Surgical Safety Checklist to Reduce Morbidity and Mortality in a Global Population. *N Engl J Med* 360:491–499 . <https://doi.org/10.1056/nejmsa0810119>



32. Khalafallah YM, Bernaiche T, Ranson S, Liu C, Collins DT, Dort J, Hafner G (2020) Residents' Views on the Impact of Robotic Surgery on General Surgery Education. *J Surg Educ*. <https://doi.org/10.1016/j.jsurg.2020.10.003>
33. Ahmed K, Khan R, Mottrie A, Lovegrove C, Abaza R, Ahlawat R, Ahlering T, Ahlgren G, Artibani W, Barret E, Cathelineau X, Challacombe B, Coloby P, Khan MS, Hubert J, Michel MS, Montorsi F, Murphy D, Palou J, Patel V, Piechaud PT, Van Poppel H, Rischmann P, Sanchez-Salas R, Siemer S, Stoeckle M, Stolzenburg JU, Terrier JE, Thüroff JW, Vaessen C, Van Der Poel HG, Van Cleynenbreugel B, Volpe A, Wagner C, Wiklund P, Wilson T, Wirth M, Witt J, Dasgupta P (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>
34. Al-Jundi W, Wild J, Ritchie J, Daniels S, Robertson E, Beard J (2016) Assessing the nontechnical skills of surgical trainees: Views of the theater team. *J Surg Educ* 73:222–229 . <https://doi.org/10.1016/j.jsurg.2015.10.008>
35. Prineas S, Mosier K, Mirko C, Guicciardi S (2021) Non-technical Skills in Healthcare. In: Donaldson L, Ricciardi W, Sheridan S, Tartaglia R (eds) *Textbook of Patient Safety and Clinical Risk Management*. Springer International Publishing, Cham, pp 413–434
36. Raison N, Wood T, Brunckhorst O, Abe T, Ross T, Challacombe B, Khan MS, Novara G, Buffi N, Van Der Poel H, McIlhenny C, Dasgupta P, Ahmed K (2017) Development and validation of a tool for non-technical skills evaluation in robotic surgery-the ICARS system. *Surg Endosc* 31:5403–5410 . <https://doi.org/10.1007/s00464-017-5622-x>
37. Diamond IR, Grant RC, Feldman BM, Pencharz PB, Ling SC, Moore AM, Wales PW (2014) Defining consensus: A systematic review recommends methodologic criteria for reporting of

- Delphi studies. *J Clin Epidemiol* 67:401–409 . <https://doi.org/10.1016/j.jclinepi.2013.12.002>
38. Zhao B, Lam J, Hollandsworth HM, Lee AM, Lopez NE, Abbadessa B, Eisenstein S, Cosman BC, Ramamoorthy SL, Parry LA (2020) General surgery training in the era of robotic surgery: a qualitative analysis of perceptions from resident and attending surgeons. *Surg Endosc* 34:1712–1721 . <https://doi.org/10.1007/s00464-019-06954-0>
39. Kumar R, Hemal AK (2006) The “scrubbed surgeon” in robotic surgery. *World J Urol* 24:144–147 . <https://doi.org/10.1007/s00345-006-0068-0>
40. Fong Y, Buell JF, Collins J, Martinie J, Bruns C, Tsung A, Clavien PA, Nachmany I, Edwin B, Pratschke J, Solomonov E, Koenigsrainer A, Giulianotti PC (2020) Applying the Delphi process for development of a hepatopancreaticobiliary robotic surgery training curriculum. *Surg Endosc* 34:4233–4244 . <https://doi.org/10.1007/s00464-020-07836-6>
41. Burden C, Fox R, Lenguerrand E, Hinshaw K, Draycott TJ, James M (2014) Curriculum development for basic gynaecological laparoscopy with comparison of expert trainee opinions; Prospective cross-sectional observational study. *Eur J Obstet Gynecol Reprod Biol* 180:1–7 . <https://doi.org/10.1016/j.ejogrb.2014.05.036>

## **FIGURE LEGENDS:**

Figure 1 - Flowchart of the Delphi process and additional survey.