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Biomedical laboratory scientists and technicians in digital pathology – Is there a need for professional development?

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Abstract

Objective: Digital pathology (DP) is moving into Danish pathology departments at high pace. Conventionally, biomedical laboratory scientists (BLS) and technicians have prepared tissue sections for light microscopy, but workflow alterations are required for the new digital era with whole slide imaging (WSI); digitally assisted image analysis (DAIA) and artificial intelligence (AI). We aim to explore the role of BLS in DP and assess a potential need for professional development.

Methods: We investigated the roles of BLS in the new digital era through qualitative interviews at Danish Pathology Departments in 2019/2020 before DP implementation (supported by a questionnaire); and in 2022 after DP implementation. Additionally, senior lecturers from three Danish University Colleges reported on how DP was integrated into the 2023 bachelor's degree educational curricula for BLS students.

Results: At some Danish pathology departments, BLS were involved in the implementation process of DP and their greatest concerns were lack of physical laboratory requirements (69%) and implementation strategies (63%). BLS were generally positive towards working with DP, however, some expressed concern about extended working hours for scanning. Work-task transfers from pathologists were generally greeted positively from both management and pathologists; however, at follow-up interviews after DP implementation, job transfers had not been effectuated. At Danish university colleges, DP had been integrated systematically in the curricula for BLS students, especially WSI.

Conclusion: Involving BLS in DP implementation and development may benefit the process, as BLS have a hands-on workflow perspective with a focus on quality assurance. Several new work opportunities for BLS may occur with DP including WSI, DAIA and AI, and therefore new qualifications are warranted, which must be considered in future undergraduate programmes for BLS students or postgraduate programmes for BLS.

Keywords

Digital pathology, medical technologist, clinical laboratory scientist

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Introduction

In pathology laboratories, the implementation of digital pathology (DP) is a globally growing trend as technological performance increases for DP hardware and software including scanners, whole slide imaging (WSI); digitally assisted image analysis (DAIA) and artificial intelligence (AI). When introducing the fully digitalized transformation of laboratories, significant changes in workflows must be expected.[1] These changes may include a more cautious preparation of glass slides, scanning, WSI, digital distribution and storage. With these new workflows, not only pathologists will be affected but also laboratory technicians. In Denmark, and most other European countries, these professionals have the title of biomedical laboratory scientists (BLS). In other countries and regions, they may be referred to as biomedical laboratory technologists, medical laboratory technicians, or variations of those.[2,3] In Denmark, BLS are the main professionals working in the pathology laboratories, handling the preanalytical workflow.[4] Educating BLS takes 3½ years in Denmark and is classified as a professional bachelor's degree in biomedical laboratory science. BLS possess theoretical expertise and hands-on skills in biomarker analysis, validation, and quality assurance (QA), including in the subject clinical pathology.[2,5]

Traditionally, BLS have been involved in the receival of tissue samples; preanalytical tissue fixation; embedding; sectioning; glass mounting, and analytical staining procedures. Subsequently, BLS have delivered the glass slides to the pathologists, and manually archived them after completed diagnostics. With a full DP workflow, the optimized preparation of slides for scanning and the scanning of slides are laborious additions, however, it will no longer be required to manually distribute glass slides to the pathologists.[6] There are concerns about discarding glass slides immediately after scanning,[4] and a robotic solution for archiving glass slides may be a solution to ease the manual work of the BLS.[7]

DP implementation teams should ideally involve all relevant professions, such as management, pathologists, and laboratory staff like BLS.[4,8] In one Danish region (Region of Southern Denmark), all professions assisted in implementing DP with a transition to full histological DP in 2021.[4,7,9] For the DP implementation process, best practice recommendations include creating awareness about DP in the department; establishing appropriate work conditions and workflow; and ensuring that team members from various professions are part of the implementation process.[4,9,10] To our knowledge, laboratory staff, like BLS, are not professions of attention in the literature,[11] also when studying DP implementation, although challenges in the laboratory workflow are identified as important focus points.[12] The best practice recommendation is a multidisciplinary approach for the implementation process, hence also including BLS[4,8,12]

In a national study of Denmark, we previously mapped Danish experiences and approaches when implementing DP focusing on pathologists and management.[4] In this study, we aim to investigate the role of BLS before and after full DP implementation. Given the global shortage of pathologists,[13] we investigate potential and actual work transfers to BLS. With interviews, we mainly have a qualitative focus, and we include perspectives on education and attitudes among BLS regarding DP. As senior lecturers at BLS bachelor's programmes from three different Danish University Colleges, we will also describe adaptations in our educational curricula to accommodate the new era of DP in Denmark.

Methods

The primary method of this study is qualitative data. We conducted individual interviews regarding BLS and DP before full implementation and a focus group interview after complete implementation. Additionally, the study incorporates a limited amount of quantitative data obtained from a questionnaire administered before the interviews. Finally, senior lecturers from three Danish university colleges provided information on how DP was integrated into the education for BLS in the year 2023. The methods for each study are explained in detail below.

Questionnaire

Our questionnaire, created using SurveyXact (Rambøll, Denmark), was distributed to BLS clinical directors at all pathology departments in Denmark (n = 13), with an encouragement to forward the e-mail containing the questionnaire link to all staff members. The link was accessible for three months, from June to August, 2019. Additionally, we distributed flyers; made posts in two relevant Danish pathology groups on Facebook; and included an announcement in a journal for members of the Danish BLS trade union. Parts of this national study have previously been published in Smith et al.,[4] which primarily focused on opinions from management and medical doctors (MD) on DP. This present study has a different aim, and only data from BLS working with DP (n = 26) were filtered in data analysis for this paper (for comparison, 231 respondents (62% BLS (143/231)) in total completed the questionnaire corresponding to approximately 18% (231/1300) of all staff members working at pathology departments in Denmark. Of those, 5% (70/1300) claimed they were working with DP in the questionnaire (*i.e.,* 3% MD and 2% BLS)). The questionnaire consisted of a total of 91 questions and was designed to direct only relevant questions for the respondent depending on factors such as profession, experience with DP, or managerial role. For further information of the survey method and results,

including details on how BLS experienced disadvantages and advantages of DP compared to pathologists and directors, we refer to Smith et al..[4] For descriptive statistical analysis, Excel Microsoft Office 365 (Microsoft, Redmond, WA, USA) was applied; Graph Pad Prism 10 was applied to illustrate data and to perform Fisher's exact test ($\alpha = 0{,}05$).

Interviews

Expectations to full DP implementation – individual interviews. From November 2019 to January 2020, we conducted ten individual interviews at eight of the thirteen Danish pathology departments distributed across all five regions of Denmark.[14] The 10 informants were selected based on diversity in geographical region, age, sex, and profession, which included directors, pathologists, and BLS, see Table 1. Written informed consent forms were obtained from informants before each interview. The interviews were performed individually, they were audio-recorded and took place at the informant's workplace, lasting between ½ and 1 h. Informants were interviewed in the Danish language by one primary interviewer with an observer assisting the process (both authors). A semi-structured interview guide with open-ended questions was used, and unstructured questions were added as the interview progressed. The clean verbatim method was employed for transcribing the audio-recordings. The finalized transcripts were analyzed by the authors, and the data were categorized under thematic headings, with citations translated from Danish to English. It is worth mentioning that only parts of four of the interviews were previously published in Smith et al.[4] However, the present study has a different aim and focus (BLS). Hence only information not previously published is included in this study.

Table 1. Professions of the informants for the ten individual interviews from 2019/2020. The informants represented all the five Danish regions, but only 8 of the 13 pathology departments in Denmark.[14] Departments are specified with codes to maintain anonymity (regarding the group interview performed in 2022 four BLS participated from Region of Southern Denmark, but they are not shown in this Table).

Region	Department code	Informants for the interviews
Region of Southern Denmark	A	BLS Expert, MHS
	A	Chief Pathologist
	A	BLS Clinical Director
	B	BLS IT Expert
	C	Chief Pathologist
Region Zealand		BLS, Clinical Teacher for BLS students
Capital Region of Denmark		BLS Generalist
Central Denmark Region	1	BLS DP Expert
	2	Chief Pathologist
North Denmark Region		MD Clinical Director

BLS: biomedical laboratory scientist; DP: digital pathology; MD: medical doctor; MHS: Master of Science in Health Science.

After full DP implementation – BLS focus group interview. Two years later, in March 2022, a comprehensive DP workflow was fully integrated for histological samples in Odense, Region of Southern Denmark. This was the first department in Denmark and thus an early adopter of DP in a Danish context.[15] Consequently, we selected this department for a follow up study and conducted a semi-structured focus group interview. The focus group comprised of four BLS that did not participate in the previous individual interviews. They were chosen based on their experience, age, and gender, to ensure a heterogenic group. One interviewer and one observer, which were also both authors (and may be a limitation to the study), applied an interview guide, and the informants were asked about their experiences, expectations, and how BLS managed the changes in workflows. The interview was transcribed and analyzed using opinion condensation, and the data were coded with thematic headings.

Digital pathology in bachelor programmes for BLS in Denmark

For an educational perspective on DP in Denmark, this study includes three university colleges offering bachelor's degree programs in Biomedical Laboratory Science. The investigation outlines how DP is integrated into the curriculum of BLS students as of 2023. Information was obtained from senior lecturers from the following university colleges:

University College Copenhagen, Department of Technology, Faculty of Health, Copenhagen, Denmark, by authors MCZ and SJ, senior lecturers.

University College Absalon, Biomedical Laboratory Science, Center for Engineering and Science, Næstved, Denmark, by author CLJ, senior lecturer.

University College UCL, Biomedical Laboratory Science, Department of Biomedical Laboratory Science,

Physiotherapy, and Radiography, Odense, Denmark, by authors senior lecturer REJ and lecturer MFBN.

These five informants were also authors of this study (which may create data bias and a limitation to this part of the study) and their information was sent via email to corresponding author JS. First with one open-ended question to describe how the BLS educational programme integrate digital pathology in the curriculum. This was followed by closed questions, where each informant had to inform which hardware and software DP technologies were available for the students, including name of company. Other closed questions included filling out a table with information for each of the seven semesters on: 1. Type of DP applied, 2. Topic DP was used for, 3. Number of lessons (estimated to 45 min). Thematic analysis was employed to identify patterns and themes to organize the open-ended data. From the number of lessons ETCS were calculated, where 1 ECTS point corresponds to a study effort of 27 study lessons.[16,17]

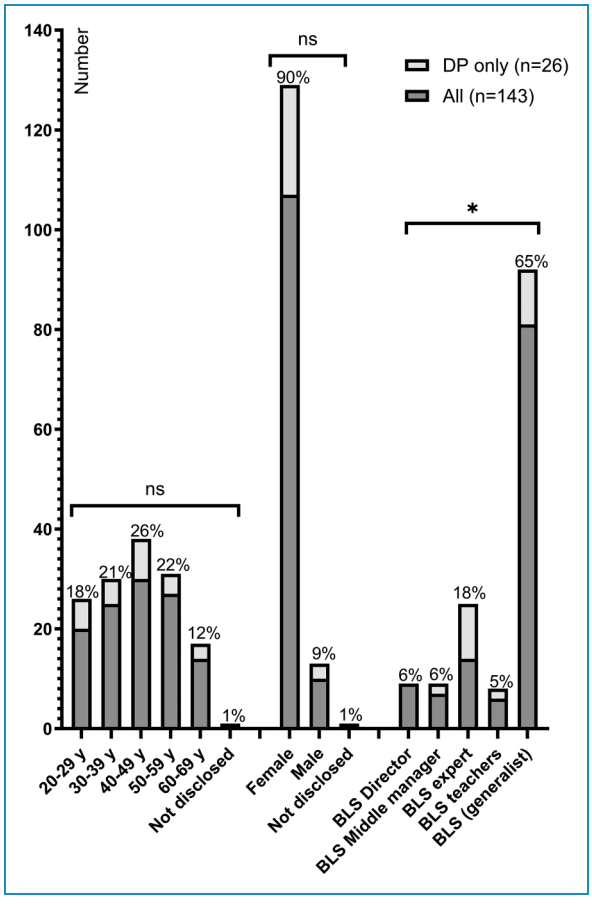

Figure 1. Age, gender, and profession of biomedical laboratory scientists (BLS) working with digital pathology (DP) compared to BLS not working with DP from our national questionnaire in 2019 in Denmark, where a total of 143 BLS responded. The percentages at each column represents the total number of BLS i.e., BLS not working with DP (dark grey) plus BLS working with DP (light grey). ns= nonsignificant; *$p < 0.05$; y = years.

Results

Results from the pathology departments were based on a short questionnaire to BLS; in depth individual interviews with different professions; and a group interview with BLS. Data from the university colleges were based on a written correspondence with senior lecturers.

Questionnaire

Only a limited number of BLS were involved in DP activities during this early stage of DP implementation in Denmark.[4] In total, n = 26 BLS were working with DP and responded to our questionnaire. This corresponds to approximately 3% of BLS (approximately n = 850 BLS worked at the 13 Danish pathology departments in 2019). A total of 143 BLS answered our questionnaire and there were no significant differences in sex ($p > 0.99$) or age distribution (p = 0.93) when compared to the staff working with DP as illustrated in Figure 1. However, among BLS working with DP, there was a significant difference in distribution of professional titles compared to the general BLS staff ($p = 0.04$), Figure 1. The majority (50%) had 0–1 years of experience working with DP, and only 12% had between 6 and 10 years of experience, as depicted in Figure 2, which also illustrates the percentage of their working day dedicated to DP. Tasks handled by the BLS included: 65%

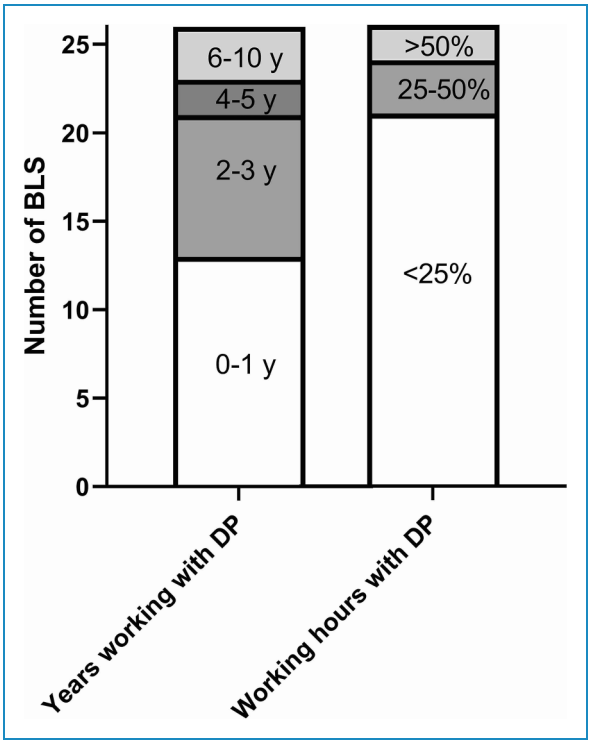

Figure 2. Number of biomedical laboratory scientists (BLS) that worked with DP in 2019: Distribution of years and hours working with DP.

involved in digital scanning; 15% in diagnostics/quality assurance and/or development of WSI and 11% in diagnostics/quality assurance and/or development of DAIA; 19% were involved with the use of DP in research and development; 15% in DP hardware/software support; 19% in the purchase of new digital equipment; 12% in the development of DP strategies; and 27% were participating in education/training of others. BLS working with the actual DP implementation (n = 16) also experienced challenges in the process, as depicted in Figure 3, highlighting that the greatest challenges were the lack of physical laboratory requirements (69%) and implementation strategies (63%); and resistance/skepticism from fellow staff members (50%).[4]

Expectations to full DP implementation – individual interviews

This study about BLS and DP, involved ten informants who underwent individual interviews. They represented all five regions in Denmark,[14] and eight out of the thirteen Danish pathology departments. Table 2 provides insights from the interviewed informants, underscoring that during the interviews, DP was still in its nascent phases in Denmark in 2019/2020. The interviews are summarized and categorized below, with actual quotes available in the Supplementary section.

BLS and DP - attitudes. The interviews with various stakeholders provided insights into the attitudes and perspectives surrounding BLS and the implementation of DP.

Pros and cons. The three BLS informants already working with DP were enthusiastic to take on the new opportunities that DP provided. However, the three informants recognized that not all fellow BLS staff were positive, but found that some BLS colleagues were indifferent to the new digital era, and some even worried about DP mainly due to extended working hours. The interviews highlighted different categories of technology acceptance among BLS, including "acceptors," "skeptics," and "doubters." The significance of understanding and addressing the concerns of the latter group was emphasized.

A pathologist expressed concerns about DP potentially imposing additional work tasks on BLS without gains and no opportunity for BLS to work from home, like DP can offer pathologists.

A BLS DP Expert acknowledged a healthy scepticism among BLS colleagues, attributing it to a pressured work environment. However, there was also eagerness for DP

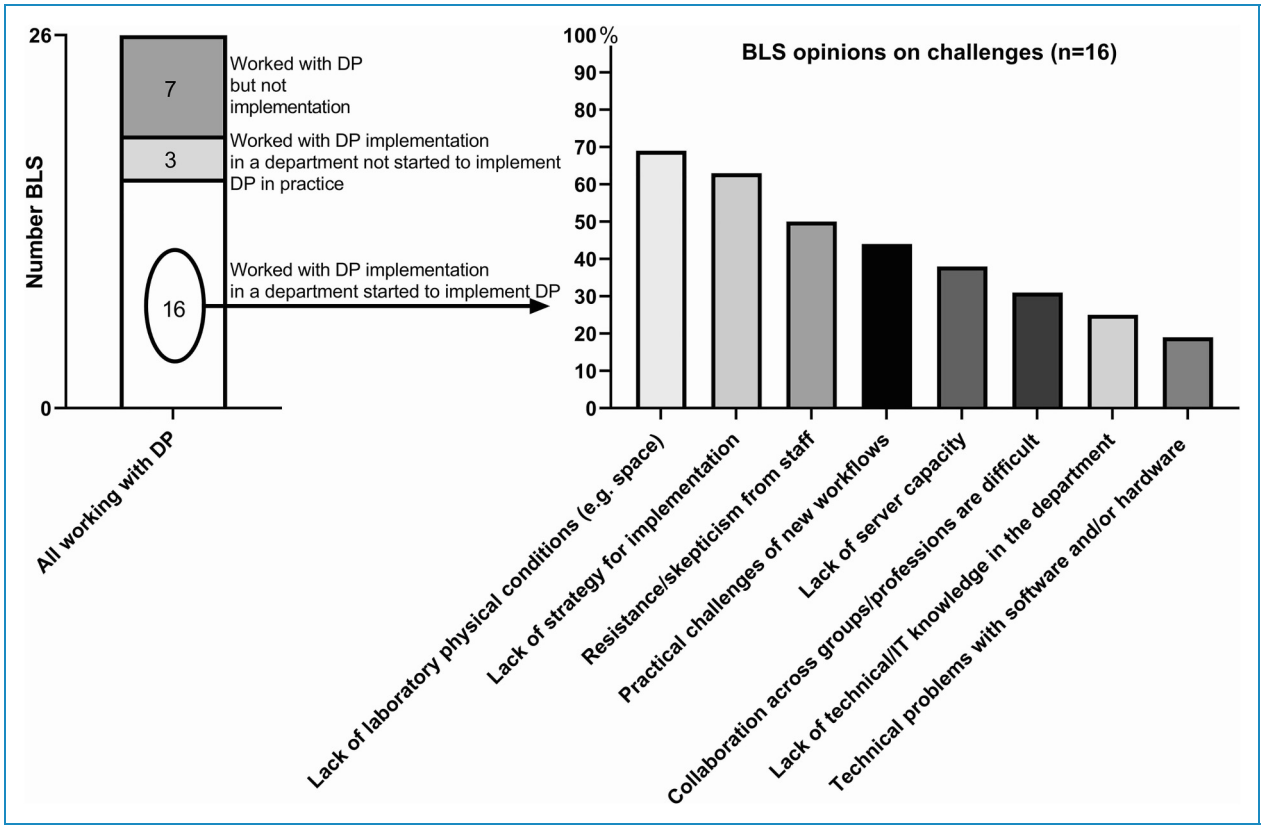

Figure 3. Biomedical laboratory scientists (BLS) working within digital pathology (DP) in 2019, from the questionnaire. The figure shows the distribution of opinions on challenges in the implementation process among BLS working with the actual DP implementation.

Table 2. Status of DP and how BLS were included in DP at the departments according to interviewed informants in 2019.

Pathology department	Roles of BLS in DP and status of DP at the departments
Region of Southern Denmark	
Department A	All slides were scanned by secretaries after primary diagnostics. Breast cancer primary diagnostics with DAIA, (two BLS trained for this) Preparation for full DP implementation ultimo 2021 throughout Region of Southern Denmark BLS middle manager and BLS clinical director deeply involved in the implementation process. BLS expert participated in building an archiving robot.
Department B	Breast cancer primary diagnostics with DAIA. BLS IT expert and a research BLS assisted research projects using DP.
Department C	Breast cancer primary diagnostics with DAIA.
Region Zealand	Breast cancer primary diagnostics with DAIA. Four BLS (one expert in IT) assisted pathologists in DP research projects including DAIA. BLS IT expert and BLS involved in a large tender process for purchase of scanners for the whole region.
Capital Region of Denmark	Four BLS IT-experts scanned and sent images to external pathologist for cases in primary diagnostics. One BLS included in DP research projects including configuring DAIA.
Central Denmark Region	
Department 1	Regional project to implement WSI for dermatology cases for external pathologists. Four BLS involved in research projects regarding DP implementation, scanning, ROI, WSI and DAIA.
Department 2	BLS IT expert scanned slides for above-described regional DP dermatology project. Awaits Region of Southern Denmark for results of their full DP implementation.
North Denmark Region	DP was applied for external gastrointestinal pathologist (in Sweden) due to lack of pathologists. For this, the scanning was only performed by secretaries. BLS ascertain quality of scanned images for research projects focused on use and quality assurance of DP

BLS: biomedical laboratory scientist; DAIA: digital assisted imaging analysis; DP: Digital pathology; ROI: region of interest; WSI: whole slide imaging.

implementation among the informant's BLS colleagues, with expectations of new critical questions for implementation and finding innovative solutions.

Managerial challenges. The BLS clinical director acknowledged challenges, noting that concerns and resistance were more prominent among MD than in the BLS group. However, at another department, internal BLS job postings for DP roles faced challenges, and lack of interest may have indicated potential barriers to adoption.

Overall consensus on DP as the future. There seemed to be an overall consensus among all ten informants that digital pathology is the future. The timing, format, and ensuring quality for patients were recognized as important factors in the eventual adoption of DP.

New job assignments and work task transfers to BLS

The intersection of economy and skills. When addressing potential work task transfers to BLS resulting from the implementation of DP, the BLS clinical director emphasized the importance of aligning economy and skills. The director advocated for assigning tasks to the most qualified individuals at the lowest salary level. However, if skills are lacking within the BLS group, alternative professions, such as molecular biologists or biologists, could be considered.

Already ongoing job transfers to BLS. A pathologist mentioned that work transfers from pathologists to BLS had already commenced. Specifically, tasks related to Oncotopix and Mammae receptors had been delegated to BLS, streamlining the analysis process. The pathologist highlighted the potential for future advancements in digital and artificial reading, suggesting that certain tasks might not require the immediate presence of a MD.

Moreover, another pathologist pointed out the ongoing transfer of work tasks to BLS. For instance, BLS trained to evaluate polyps have been performing this task for years, and there is a growing consensus on the delegation

of certain diagnostic steps to BLS, when aided by the digital tools, like AI.

BLS part of innovation and developing new technology. In the context of developing robotic technology for archiving, the MHS BLS from Southern Denmark region played a pivotal role, and emphasized the significance of having BLS on an innovative team who understands and can effectively communicate with other BLS, facilitating the development of new laboratory DP technology.

BLS responsible for scanning. All ten informants highlighted the likelihood of only BLS assuming the additional tasks of scanning, which has been performed by secretaries or BLS in different departments. A pathologist noted that BLS will be responsible for scanning due to their awareness of slide quality. The pathologist also suggested an increasing need for IT-specialized BLS in a more digitalized environment.

Anticipation of job transfers due to the shortage of pathologists. Furthermore, a BLS teacher expressed confidence in job transfers from pathologists to BLS due to DP and the apparent shortage of pathologists. Anticipating changes in the BLS profession, the teacher noted that MD viewed these changes positively, driven partly by the necessity to manage their substantial workload.

The MD clinical director highlighted existing work transfers related to the identification of regions of interest (ROI) in digital pathology. BLS was seen as valuable in quality assessing analytical steps, ensuring the digital image's quality, and identifying potential artifacts. The director also emphasized the national challenge of recruiting pathologists and expressed the need to delegate tasks to alleviate the workload.

In conclusion, the perspectives provided by various stakeholders underscore evolving job tasks for BLS in the context of digital pathology, with a growing recognition of the potential role of BLS in handling certain responsibilities traditionally associated with MD.

Work transfer away from BLS. Digitalization and technology have the potential to alleviate BLS professionals from certain manual tasks. An example of this advancement is the development of a robot for archiving slides, as highlighted by the MHS BLS. At their department, BLS manually load glass slides onto racks, slides are scanned (NanoZoomer S360 (regular slides) and Nanozoomer S60 (macro slides), Hamamatsu Japan), and subsequently the rack is manually moved to the archiving robot, which registers each glass slide for easy retrieval via a screen on the robot. The archiving robot then places the slides in an available spot. After three weeks, the robot automatically discards the slides. Both the MHS BLS and the MD clinical director envision a future where robot technology plays a pivotal role to streamline operations and increase efficiency for the entire scanning process with manual work replaced by robotic assistance for the loading, scanning, and archiving of slides.

BLS and education for new job assignments. In adapting to the evolving era of digital pathology, new skills may be required.

Development on the department. The MHS BLS was detailed regarding their departmental preparation process to go fully digital, which included a comprehensive educational program featuring presentations from a pioneering department in Leeds, England, and Sectra, the software provider. This program emphasized the collaborative nature of digital pathology, involving professionals from various fields.

In the Capital Region of Denmark, BLS underscored the need for industry collaboration to assist in and ensure employee readiness for digital pathology, including equipment operation around the clock and handling breakdowns.

A BLS DP expert outlined an upcoming training program regarding DP in primary diagnostics for 6–8 BLS staff members. This included emphasizing preanalytical QA, crosstalk between IT systems, DAIA protocol, and the significance of ROI. The expert stressed the industry to have the primary role in developing DAIA, calling for AI deep learning to streamline primary diagnostics.

At the university college. A BLS IT expert emphasized the generational shift brought about by DP and suggested incorporating more IT knowledge into the BLS curriculum. Another BLS teacher from Region Zealand highlighted the relevance of robot technology and DP QA in the BLS bachelor's degree curriculum, and also proposed additional focus on pathological anatomy for less complex organs due to the MDs' existing work pressure.

For the bachelor's degree curriculum, a BLS DP expert proposed learning scanning, calibration, digital technology, ROI, and possibly building a simple DAIA.

Acknowledging the increasing role of digital equipment in the future, a Pathologist from Central Denmark Region emphasized the need for BLS experts with IT knowledge, particularly in troubleshooting scanners. However, the pathologist suggested minimal changes to the existing BLS basic education.

In summary, three of four MD (including one MD clinical director) suggested that BLS could be involved in the diagnostic work answering simple samples assisted by DAIA or AI, which requires a greater focus on pathoanatomic knowledge. Additional IT skills for BLS were also suggested by two BLS specialists and one pathologist. All professions agreed that QA for DP should remain a focus for the BLS profession. Finding a balance between foundational education and adapting the BLS education to meet

emerging needs is essential for a smooth integration of DP practices as technology advances.

After full DP implementation – BLS focus group interview

The following results are from a focus group interview in 2022 with four BLS (Odense, Region of Southern Denmark), one year after full implementation of DP in 2021. At this department, six NanoZoomer S360 scanners and two Nanozoomer S60 scanners were used in daily routine production.[7] The scanned tissue slides were handled by the Image Management System from Sectra (Linköping, Sweden). It was estimated that around 1600 tissue slides were scanned and handled daily during a five-day work week.

Change in workflow for BLS. Despite the implementation of DP, manual workflows persisted in various stages, from sample reception to covering stained slides. Informants expressed a continued pride in manual laboratory skills, emphasizing the enduring craftsmanship culture within pathology departments.

The introduction of DP brought a notable change in BLS roles, particularly in the scanning step. Technical readiness became imperative, requiring proficiency in handling different software systems.

However, the new scanning procedure introduced delays in diagnostic workflows, prompting workflow optimization measures. These included adjusted working hours, with BLS scanning from 6 am to 4 pm, and the use of a heating cabinet to expedite slide drying. On the positive side, the digitalized distribution of slides became more efficient, requiring only one BLS for the task.

Quality assurance and DP. Informants detailed the transformation of QA procedures in the DP era. QA now focuses on ensuring the quality of tissue staining and scanning, with assessments conducted on-screen. DP offers the advantage of improved overall quality by enabling BLS to reflect on preanalytical procedures, emphasizing proper embedding and sectioning for enhanced slide quality.

On task transfers to BLS. In the Odense department of the Southern Denmark region, work transfers from pathologists to BLS had not occurred post-DP implementation. Nevertheless, BLS informants anticipated future task transfers, envisioning scenarios where BLS could handle tasks on-screen, potentially assisted by AI. This expectation aligns with the ongoing development of the profession, reflecting a shift in responsibilities and the integration of advanced technologies in daily tasks.

BLS university colleges and DP

In Denmark, the bachelor's degree in biomedical laboratory science is a 3,5-year programme (ECTS 210[16,17]), which is offered at six University Colleges across all five regions. The Danish education provides a theoretical basis in *e.g.*, anatomy, physiology, pathology, technology, statistics, and QA, however, a third of the education is practically orientated and takes place in clinical laboratories, *e.g.,* in pathology, microbiology, biochemistry, genetics, nuclear medicine, neurology or immunology. The individual university college autonomously decide to what extent DP may be incorporated in the curriculum, but general QA and emerging technologies, like robotics and computational thinking, have been a continual focus in the education. Initiatives specifically designed for DP have also been incorporated in the BLS curriculum. Table 3 summarizes topics and ETCS[16,17] for DP incorporation in the curriculum at University College Copenhagen (KP)),[18] University College Absalon (Absalon))[19] and University College UCL (UCL).[20] The part of the education taking place in the clinical laboratories may also allow students to acquire knowledge about DP if the students have been placed at a pathology department (not included in Table 3).

Software and hardware for DP. For WSI, KP applied Cirdan PathXL Tutor (Cirdan, Uk); Absalon used the open-source software for image analysis from QuPath[21]; and UCL the Nanozoomer Digital Pathology (NDP) system (Hamamatsu Photonics, Japan). Currently, KP is exploring the integration of AI into the curriculum. At UCL, the implementation of a course with a DP scanner (NanoZoomer 2.0 RS, Hamamatsu Photonics) is underway in the simulation laboratory ultimo 2024 to provide students with firsthand experience, emphasizing the crucial role of pre-analytical procedures in achieving satisfactory scans.

Semesters. In the initial semesters at all university colleges, students were acquainted with the entire process from tissue preparation to conventional light microscopy. WSI was introduced alongside conventional microscopy for human normal or pathological histology from the first or second semesters and forward to ensure that the students gained an understanding of the possibilities, advantages, and limitations of both conventional microscopy and WSI, Table 3. KP uses primarily WSI as a preparation tool prior to conventional microscopy lessons, whilst WSI is incorporated in the teaching lessons at both Absalon and UCL. For WSI, students applied premade tissue slides or slides self-prepared through histochemical or immunohistochemical (IHC) methods.[19–21]On the 5th semester at UCL, students utilized WSI in a breast cancer case assignment, evaluating molecular subtypes based on IHC markers (HER2, ER and Ki67). Similarly, at

Table 3. How DP is incorporated in the BLS bachelor's degree curriculum in Denmark. The table shows semesters, topics, type of DP and number (n) of lessons. Lessons at campus (groupwork, lectures or other) and preparation is specified as 1:1 unless stated otherwise. One lesson is estimated to be 45 minutes,1 ECTS point corresponds to a study effort of 27 study lessons. [17,18]

	KP (Capital Region of Denmark)			Absalon (Region Zealand)			UCL (Region of Southern Denmark)		
Semester	**Topics**	**Lessons**	**Type**	**Topics**	**Lessons**	**Type**	**Topics**	**Lessons**	**Type**
1st							- Hematology - Histology: Muscles	9	WSI WSI
2nd	- Introduction to tissue types - Histology: Muscles, pulmonary, digestive tract (preparation) - Special stains (preparation)	2 6 2	WSI WSI WSI	- Histology: Cardiac, liver, digestive system, lungs, muscle, kidney, thyroid - Special stains	27	WSI	- Histology: Digestive tract, lungs, liver and kidneys	5	WSI
3rd							- Histology: Thyroid, pancreas - IHC: Colon cancer - Introduction to AI/DAIA	13	WSI WSI DAIA
4th	Histology: Kidneys (preparation)	2	WSI	- Histopathology - IHC: Colon/breast cancer, melanoma	54	WSI			
5th	IHC (preparation)	2	WSI				IHC: Breast cancer	8	WSI
6th									
7th	Two-week course in DP (2/3 of all students (elective)) *Optional: Bachelor project with DP (10 projects completed)*	82 *20 ETCS*	WSI DAIA	*Optional: Bachelor project with DP*	*20 ETCS*		*Optional: Bachelor project with DP (4 projects completed)*	*20 ETCS*	
ECTS in total	**3,6**			**3**			**1,3**		

Absalon: University College Absalon; AI: artificial intelligence; BLS: biomedical laboratory scientists; DAIA: digitally assisted image analysis; DP: digital pathology; ECTS: European Credit Transfer System; IHC: Immunohistochemistry; KP: University College Copenhagen; UCL: University College UCL; WSI: whole slide imaging.

Absalon on 4th semester WSI was applied for cases on malignant melanoma, colon and breast cancer to evaluate histopathological development and IHC markers (HER2, Ki67, CK7 and CK20).

Elective DP course at KP. In the final semester, KP offered an elective two-week DP module where students engaged with WSI and DAIA on specific cases. They utilized scanned slides, worked with data generation using relevant apps (Visiopharm, Hørsholm), applied data processing, and presented their findings. The focus was on quantification of Smooth Muscle Actin, CD31 and Ki-67 IHC expression.

The bachelor thesis. All three university colleges collaborated with clinical practice and research laboratories during the fourteen-week bachelor thesis on the final 7th semester. DP has been a prominent subject in several projects, providing students with hands-on experience in scanning, WSI, DAIA and, occasionally, simple app development. Notably, two students were involved in a publication testing a new scanner for the intraoperative laboratory[22]

Discussion

In pathology laboratories, BLS have traditionally been the backbone in preanalytical and analytical tissue preparations and slide distribution to pathologists for diagnostics based on light microscopy. A new digital era is slowly but steadily gaining ground in Danish laboratories and globally; and DP will have an enormous impact on workflows once the laboratories are fully digitalized. In this study, we focused on the role of BLS in the new DP era – now and in the future - in the laboratories and in education.

BLS and DP - attitudes

Reorganizing and adjusting to a new DP laboratory workflow may be challenging[1] including addition of the laborious scanning procedure.[12] Region of Southern Denmark (Department A) had to extend working hours and employ more BLS staff for the scanning procedure when they went fully digital.[4] From our interviews this was mainly a concern among staff members before going fully digital, however, from the group interview after implementation this was no longer a concern. Possibly because innovation partly solved the prolonged working hours for BLS, like development of the archiving robot.[7] However, this behavior is also in line with reports from other countries; once DP has been implemented the new technology and workflow is accepted.[23]

From the questionnaire resistance and skepticism from fellow staff was quantitatively the third biggest challenge for BLS working with DP. In change management, skepticism is an expected challenge,[24] but may also be a positive attribute. The positive effect depends on how skeptics are perceived and managed by the organization, such as listening to staff members and letting them become positively engaged in the change to avoid inappropriate impact of skepticism and resistance.[24,25]

The BLS clinical director found less scepticism and resistance among BLS than MD during DP implementation, and at this department BLS were highly included in the implementation process with a large focus on change management.[4,7] The greater skepticism and resistance among MDs may be because they are responsible for the diagnostic results, even when relying solely on DAIA and AI algorithms.[26]

Work task transfers and new job assignments to BLS

There is a shortage of healthcare professionals, which is expected only to get worse, and this may make work-task transfers between professions necessary.[27] Based on lack of pathologists, one Danish pathology department in Hjørring has already controversially transferred some diagnostics based on histology to BLS, such as evaluating ductus deference from sterilizations and screening of intestinal polyps.[28–30] This has been an inspiration for Norwegian pathology laboratories,[30] and the success may also inspire the DP movement for work transfers from pathologists to BLS, supported by the applications of DAIA and AI. This is possible in Denmark according to the medical authorization law, where delegation of tasks to assistants is allowed under the supervision and responsibility of the MD.[31] A recent Delphi study across Europe, North America, Japan and New Zealand did not reach consensus on the question whether other professions, such as BLS, should participate in AI-assisted diagnostics by 2030, however, a slight majority was supporting the notion and possibilities depend on national laws and regulations.[32]

There is also an expected shortage of BLS, not just pathologists,[33] and providing continuous development opportunities is a key factor in promoting job retention.[34] This could be work transfers, but also to include BLS in innovation projects for a successful DP workflow.[2] As an example, from our study the clinical director for BLS mentioned that wet mounting agent on slides is problematic for scanners, so DP was not yet possible in the fast frozen intraoperative laboratory. Here BLS expertise could participate in finding solutions and the issue highlights that innovative laboratory projects are important for the new DP workflow.[2]

BLS education for DP and work task transfers

The implementation of DP as a new laboratory standard may require BLS to learn new skills.[8] If this starts to include certain work-task transfers from pathologists, this may presume that BLS has at least minimum professional prerequisites to undertake these new responsibilities, *e.g.,* more knowledge in IT and in pathological anatomy. This could be implemented in under- or post-graduate courses.

Post-graduate training may be accomplished at the departments, like in Department of Pathology, Hjørring, where BLS have been trained by pathologists for certain diagnostic histology assessments.[30] This professional development in Hjørring even resulted in a postgraduate Diploma of Health course in Denmark to support this idea of work-task transfer.[35] Also, in this course for BLS, DP has been an excellent tool with access to a large pool of digital images.[36] Similarly, a study from UK identifies that introduction of BLS in areas of pre-reporting and screening requires close training and supervision by a pathologist.[37] The future prospects for BLS in pathology could possibly attract and retain BLS but may also appeal to BLS students. It is necessary that BLS education attract more students as there is a contemporary worldwide shortage of qualified BLS personnel.[33]

BLS may work in clinical laboratories of hospitals, pharmaceutical companies, biomedical research, and the biotech industry.[2,5] A relevant question is therefore whether the current bachelor's degree curriculum addresses the growing need for candidates with adequate digital competences. As a note, educational curricula may possibly vary across countries, and adaptations to embrace DP should be addressed accordingly. In this study, we described the curricula from three university colleges, on how we have developed our curriculum for the new DP future, like the introduction of WSI and DAIA. However, we believe our high focus on QA in general and our teaching in technological understanding will also support the new graduates for a future in DP, despite not involving DP specifically. With WSI, DAIA and AI, and a possible wish for further work transfers within the diagnostic area in the future, we as educational institutions for BLS need to be aware of the trends in clinical practice and the needs for more in-depth academic training in our under- and postgraduate courses.

Conclusion

We have shown how the BLS profession will play a big part in the change from a conventional laboratory to a fully digitalized diagnostic workflow. To assist the new growing workload and the shortage of pathologists in the future, we found that staff and management at pathology departments are generally positive towards work task transfers to BLS. To fulfil new demands of DP and potential work-task transfers, it is important that undergraduate and postgraduate educational programmes revisit curricula to continuously support the future BLS.

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