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Content and methods to an e-learning solution for interpreting mammography, tomosynthesis and synthetic 2D-images

Thoughts from experienced breast radiologists on beneficial materials and methods according to previous training experiences

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Purpose of this study was to find out what kind on content and learning methods experienced breast radiologists see beneficial to be implemented to an e-learning solution to interpret mammography, tomosynthesis and synthetic two-dimension images according to their previous training experiences with new breast imaging modalities. The e-learning solutions' competency and learning outcomes are to provide overview of selected breast imaging method, aid the implementation of the method to clinical workflow and help image interpretation.

In this qualitative research five thematic expert interviews were made to gather information from experienced breast radiologists on their previous experiences on learning new breast imaging modalities. Purposive and snowball sampling method was used. Interviews were recorded with mobile application, transcript to text format and analyzed with inductive qualitative content analysis with data reduction, clustering and forming main themes to answer research questions.

According to study results e-learning solution should contain content for modality introduction and clinical content to enhance advanced knowledge about the topic. Solution should have both passive learning methods and active learning methods implemented. Passive learning methods contain study material in various forms such as visual, auditive, audiovisual and kinesthetic. Passive methods include participants inner processes to integrate gained information. Active learning methods promote student relatedness and social interaction with other participants to improve deeper understanding of the topic. Active learning methods include social tasks, information sharing with others and practical training in clinical setting as well as teaching others to promote deep understanding of the matter.

In this study e-learning was found to be suitable solution for modality introduction and help teaching new breast imaging modalities. According to results the e-learning solution should contain passive and active learning methods and content for modality introduction as well as clinical content to promote learning. Social interactions, practical training and clinical work are required to gain complete understanding of the new breast imaging modality. Because of this e-learning should be used as a part of blended learning with other teaching methods that enable social interactions in clinical setting.

Keywords	e-learning, mammography, tomosynthesis, radiology, training

Contents

Terms and abbreviations

2D – Two-dimensional

3D – Three-dimensional

3D mammography – Tomosynthesis examination, Digital Breast tomosynthesis

CAD – Computer aided detection

CC – Cranio-Caudal: Mammography projection acquired from 0-degree angle

CR – Computed radiography

CT – Computed tomography

DBT – Digital Breast tomosynthesis, 3D mammography

E-learning - Achieving information and knowledge using technology as a tool for the learning process

FFDM – Full Field Digital mammography

GDPR - General Data Protection Regulation

Interactive - program or system that involves inputs or actions from user

LM – Latero-Medial: Mammography projection acquired from 90-degree angle, with radiation entering from lateral side of the breast.

MLO – Medio-Lateral-Oblique: Mammography projection acquired from an angle between 45 – 60 degrees.

Synthetic 2D – Synthetic two-dimensional mammography image reconstructed from tomosynthesis volume

Workshop – Educational event or program to enhance skills and techniques in specific matter

1 Introduction

Breast cancer is the most common cancer for women. In 2018 there were 2.09 million breast cancers cases globally and 627 000 deaths related to breast cancer (Ferlay 2018). The five-year survival rate of breast cancer has improved globally but differs from close to 90% that is possible in developed regions with breast cancer screening programs to 60% in middle-income countries and to as low as 40% and below in least develop countries with late disease detection and limited treatment possibilities (Coleman - al 2008). Key factors to promote breast cancer treatment prognosis and increase breast cancer survival rate are the early detection of the disease and availability for improved cancer treatments (DeSantis – Ma - Godin Sauer – Newman - Jemal 2017). Even in high income countries with advanced medical care the survival rate drops to as low as 24% when disease is found later, thus shoving the need for early disease detection and improvement of metastatic disease treatment (WCRF 2017).

Diagnosis and treatment success rate are directly proportional to medical doctors' possibility to familiarize with as many individual clinical cases as possible to enable early diagnosis (Pratikakis - al 2007). Especially in radiology training with real clinical images is essential for learning. Imaging modalities increase in number and complexity which increases the need for technical and IT skills training for the radiologists (Pratikakis - al 2007). In Finnish law of health care personnel (1994/559 § 18) the obligation to continuous professional education is stated to make sure healthcare personnel will maintain and enhance their level of expertise.

This study is a part of product development of an interactive e-learning solution for radiologists to interpret mammography, tomosynthesis and synthetic two-dimensional mammography images concentrating on content analysis for Planmed Oy. Planmed Oy is a part of Finnish Planmeca Group and the company develops, manufactures and markets imaging equipment and accessories for mammography and orthopedic imaging. Products are sold through a global network of dealers and over 98 percent are exported to countries worldwide. (Planmed 2018)

International market area creates a need for global radiologists' mammography procedure training. Medical imaging business has a wide diversity of customers with variable

level of clinical experience: some might buy their third digital mammography device, and some might face the possibility to renew old analogic film mammography machines with full field digital mammography (FFDM) machine with tomosynthesis option. System application training is usually focused on the safe use of the system and image quality optimization with the customer. Radiologists who are not familiar with newest imaging modalities or who have interpreted a limited amount of clinical cases, possess the need for interactive e-learning solution to learn how to work with new features (Pratikakis - al 2007). This e-learning solution would provide fast, beneficial and safe start for the use of the system and support continuous self-improvement.

E-learning based solution would have the benefit of not being fixed on certain time or location lowering the cost of the service as well as enhancing the autonomy of the user, which will improve learning possibilities. Implemented training material could be used repeatedly as often as needed and customer could have immediate personal feedback on their learning success. Feedback is one of the key components of inner motivation that promotes learning and enables learner to reach higher.

In the next chapters study topics and key features are introduced. These include introduction of the selected breast imaging modalities and feature, the e-learning concept, learning methods and available solutions for novel breast imaging modality training. Research methods are explained in Chapter 7 and results of the research are presented in chapter 8.

2 Aim and Purpose

The purpose of this study is to find out what kind of content and methods experienced breast radiologists see the most beneficial to be implemented to an interactive e-learning solution for interpreting breast mammography, tomosynthesis and synthetic two-dimension mammography examinations. *The e-learning solutions' competency and learning outcomes are to provide overview of selected breast imaging method, aid the implementation of the method to clinical workflow and help image interpretation*. The research aims obtain ideas from healthcare specialists who have experience on these modalities and can reflect to own previous training experiences on what were and would have been beneficial to have when they were learning. From acquired information interactive e-learning portal development project can be started.

The target was not to build a final and ready solution, but to gather more understanding on suitable tools and content that are seen beneficial and important according to expert.

Research questions of the study are:
What kind of content is needed for the e-learning solution?
What kind of learning methods should be implemented to e-learning solution?

3 Selected breast imaging modalities and features

For this study three breast imaging methods were selected: Mammography, tomosynthesis and synthetic two-dimensional images. The interactive e-learning solution would be concentrating to these methods. Selected breast imaging methods are explained in next three chapters to provide introduction to them.

3.1 Mammography

Mammography is a two-dimensional (2D) x-ray examinations of breast using ionizing radiation. During mammography examination the breast is compressed between compression paddle and image receptor for the image acquiring called exposure. The used x-ray radiation is absorbed variously by different tissues in imagined breast area, allowing to differentiate fat, glandular tissue, fibrous tissue, soft tissue, lesions and calcifications from one another. Image receptor can be X-ray film, computed radiography (CR)-cassette or a digital detector. Digital detectors are used to perform electronic image capture of the radiation and to produce electronic image that is transferred from detector to image acquire station software and displayed on a monitor (Karellas - Vedantham 2013). Mammography's made with digital detectors and with one image acquisition are called Full Field Digital Mammography (FFDM).

Compression is applied to the breast to reduce the thickness of the breast and to immobilize the breast tissue during image capture. Lower breast thickness reduces the required x-ray dose, that also lowers the organ dose of the patient. Because of the compression the breast tissue is also spread to wider area reducing superimposed tissues and improving tissue visibility. Immobilization of the breast with compression prevents

motion blurring and artefacts. Due to lower amount of scattered radiation compression also improves the image quality. Basic principle of FFDM mammography image is seen in figure 1.

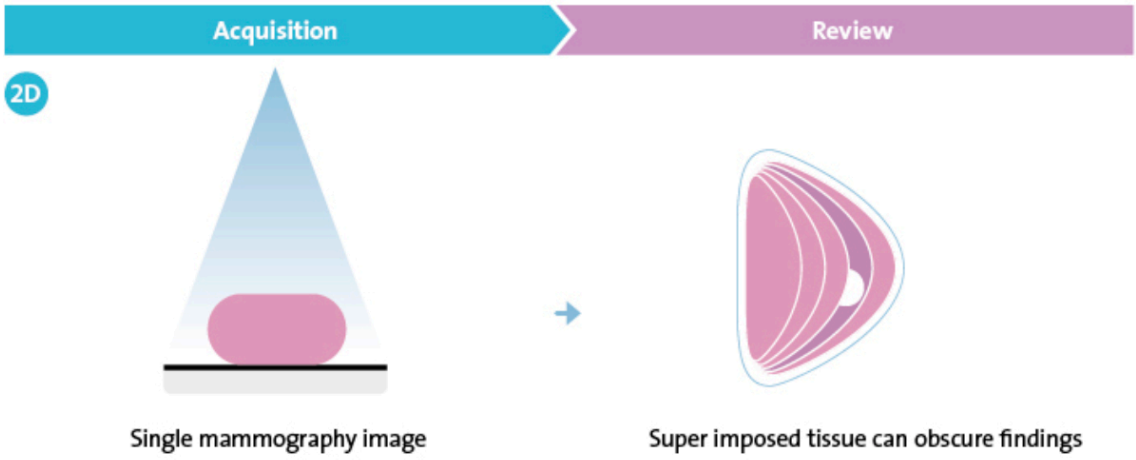

Figure 1. Demonstration of mammography image acquisition and review. (Planmed 2018)

Mammography examination is done from at least two different dimensions to improve lesion visibility and reduce false findings due to superimposed tissue. Example of mammography examination with bilateral cranio-caudal (CC) and medio-lateral oblique (MLO) views is seen in figure 2.

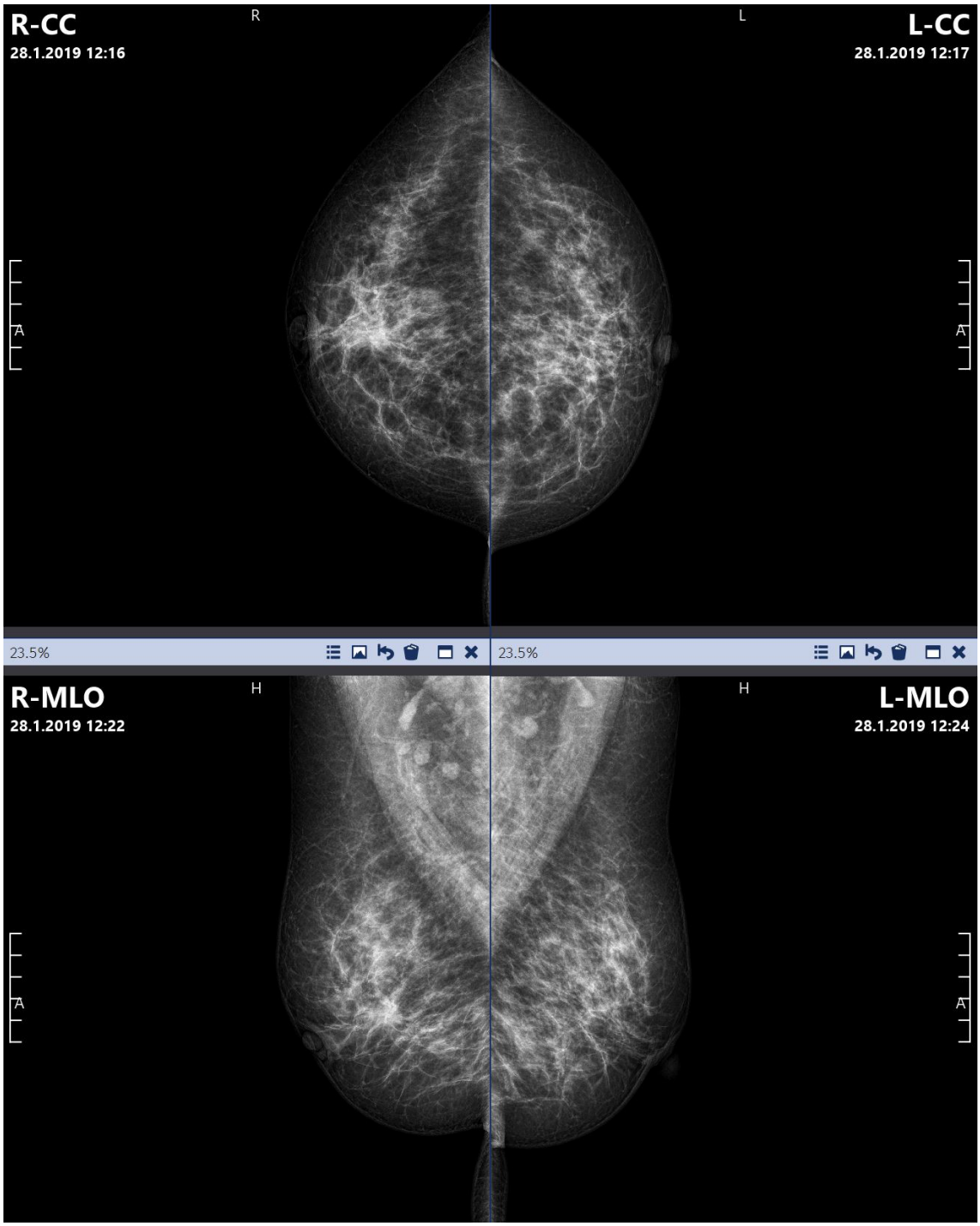

Figure 2. Example of mammography examination (Image courtesy of Dr Ferreira. Santiago de Chile, Chile)

Mammography examinations have been considered as the standard for early diagnosis of breast cancer (DeSantis, Ma, Godin Sauer, Newman, Jemal 2017). The breast examinations have evolved from film imaging to CR-systems and to FFDM system. Through this evolution image quality has improved, doses have reduced, image storing has evolved (Karellas - Vedantham 2013) and system ergonomic from the user and patient

point of view have improved. Mammography image interpreting has changed along with the mammography systems from hardcopy film reading to prints and to softcopy reading of FFDM examinations. FFDM image interpreting has evolved with the help of technical image post processing possibilities and image interpreting software tools, e.g. magnification, invert, image processing. Most recent additions are software solutions using artificial intelligence (AI) to aid radiologists image interpreting called Computer Aided Detection - CAD (Karellas - Vedantham 2013).

Mammography examinations have limitations with lesion visibility in dense breasts, thus requiring further information from special mammography views and additional ultrasound examination (Barkhausen – Rody - Schaefer 2016). When breast density increases the sensitivity, meaning cancer detection ability, of mammography examinations decreases (Nees 2013). This is because dense breast tissue areas may hide suspicious masses and densities in mammography images due to having similar x-ray absorption capabilities. Superimposed dense breast tissue areas in mammography images may also mimic false suspicious densities when tissues are overlaying and thus creating dense local areas. Overlaying dense tissue areas have more noise visible in image and this can complicate benign lesion diagnosing (Nees 2013). These scenarios reduce the specificity, the accuracy of real malignant findings, of mammography examinations. These issues have created the need to evolve mammography systems further on and to create new examination possibilities.

3.2 Tomosynthesis

Tomosynthesis is relatively new breast imaging method from early 2000 (Barkhausen – Rody - Schaefer 2016 p2). Tomosynthesis is also called Digital Breast Tomosynthesis (DBT) and 3D mammography. The tomosynthesis examination produces sliced volume from the imagined beast. This allows to gain more precise information from the midst of the breast compared to traditional two-dimensional mammography image.

Tomosynthesis examination is done with similar positioning as in conventional mammography examination with breast positioned and compressed between image receptor and compression paddle. As seen in figure 3, during the acquisition, instead of acquiring one image like in FFDM, several low dose projections are acquired from the target from various angles by moving the x-ray tube. From the projection images a high- resolution slice volume of the breast is reconstructed by reconstruction algorithm (Barkhausen – Rody -

Schaefer 2016 p4-7). The amount of the slices in the volume depends on the thickness of the compressed breast and reconstructed slice thickness. In image interpretation all tomosynthesis slices are scrolled through.

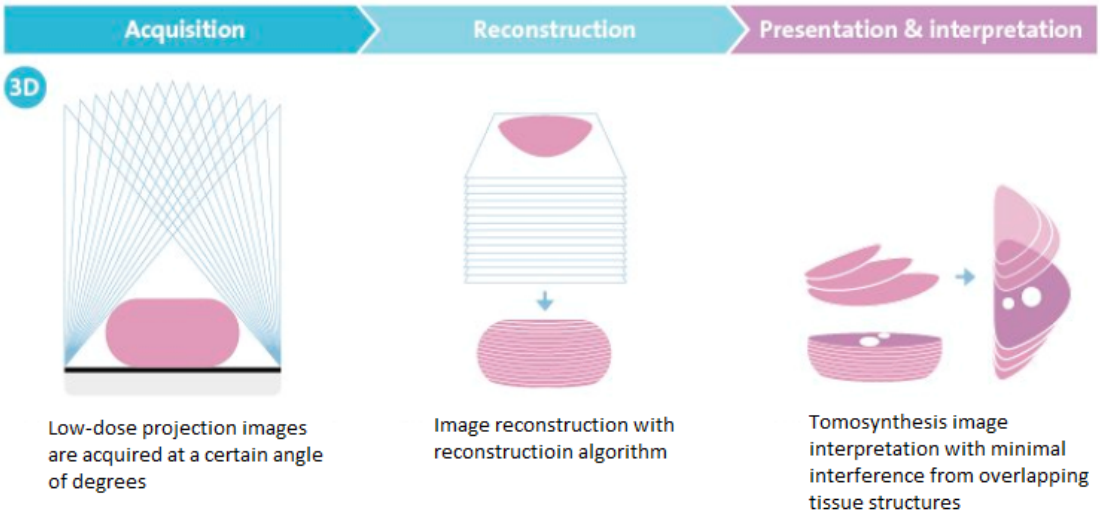

Figure 3. Demonstration of tomosynthesis image reconstruction and review. (Planmed 2018)

Tomosynthesis is called limited angle- tomography because unlike conventional Computer Tomography (CT) the tomosynthesis does not rotate the target with angle of 180 - 360 degrees, but only with a limited range from 11-50 degrees. Because of this tomosynthesis images are not accurate cubic voxels, but the third z-dimension resolution is of low quality compared to x and y-dimension resolution (Nees 2013). Thus, tomosynthesis volume, unlike CT volumes with diagnostically approved resolution quality on all three dimensions, is unable to be reconstructed in another dimension, e.g. image obtained in Cranio-Caudal (CC) position is unable to be reformatted to Latero – Medial (LM) position because the non-isotropic volume would have low resolution and image quality would not be enough for clinical image interpretation.

The non-isotropic volume is not the only reason to take several tomosynthesis projections from one breast. Studies have shown that tumors can be more prominent in one of several projections (Rafferty – Park - Philpotts - al. 2014) (Rafferty – Niklason - Jameson-Meehan 2006). This indicates that to maximize cancer detection and specificity more than one tomosynthesis projection should be acquired from one breast. Breast positioning also vary between different projections to capture maximal amount of tissue visibility

in mammography and tomosynthesis images thus creating a need to taka each tomosynthesis separately.

Limitations on tomosynthesis examinations have been microcalcification visibility and characterization because the image resolution is not as good as in normal mammography images. Tomosynthesis also has higher radiation dose compared to mammography examination, because several projections are needed to reconstruct the tomosynthesis volume (Barkhausen – Rody - Schaefer 2016 p11). The tomosynthesis image interpretation takes longer from radiologists compared to conventional mammography image as the whole volume needs to be viewed compared to the single image acquired in mammography.

3.3 Synthetic two-dimensional mammography

Synthetic two-dimensional mammography image is a single image that resembles mammography image and thus is more comparable to mammography than tomosynthesis examination. Synthetic 2D-image is not a separately acquired image. It is generated from the information found in tomosynthesis volume as a summation image (Barkhausen – Rody - Schaefer 2016 p26-27). Mammography and tomosynthesis are both considered to be imaging modalities. Synthetic 2D-image is more of a feature of tomosynthesis because it is built from data acquired during tomosynthesis acquisition.

Digital mammography images have been standard for breast disease diagnosis and tomosynthesis images were taken to acquire additional information if needed. Using combo imaging of these two imaging modalities proved to have good clinical performance, but limitations were seen in higher radiation dose with both examinations done (Margarita - Ben - Victor - al. 2014). Also comparing tomosynthesis images to conventional mammography images is seen challenging (Barkhausen – Rody - Schaefer 2016 p27). This is because mammography image is a single image and one tomosynthesis view from a breast can consist from dozens of images, depending from the breast thickness. There can be differences between mammography and tomosynthesis image post processing as well. Differences can appear in contrast and brightness variations between modalities and deviations between finding features in visibility.

To reduce unnecessary radiation dose from both examination modalities and to ease image comparison between mammography and tomosynthesis medical device manufacturers have seek solutions to replace 2D mammography images with synthetic 2D-images built from tomosynthesis projection data. Demonstration of synthetic 2D-images reconstruction and review is seen in figure 4. Study from Skaane & al from 2014 proved that synthetic 2D combined with DBT was comparable in performance to FFDM combined with DBT (Skaane – Bandos - Eben - al 2014).

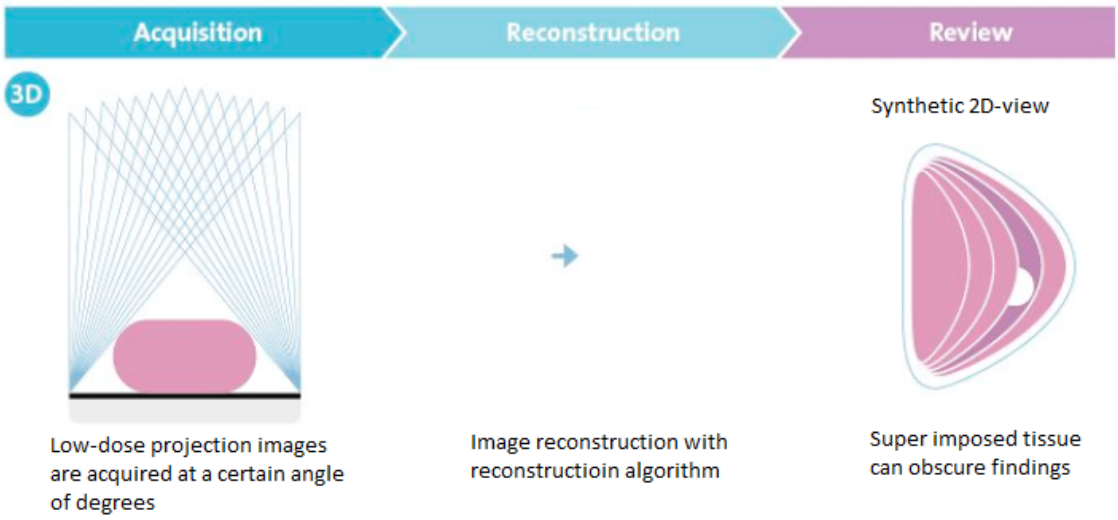

Figure 4. Demonstration of synthetic 2-image reconstruction and review. (Modified from Planmed 2018)

Synthetic 2D-images will ease the tomosynthesis data comparison to previous mammography examinations. It will also simplify the patient workflow, shorten the total examination time and lower radiation dose if conventional mammography images are no longer needed. Synthetic 2D-images contain artifacts and technical features that affect the image quality. These issues can be lower resolution in certain image area, pseudocalcification in images, artefacts near foreign body- objects and blurring artefact (Ratanaprasatporn – Chikarmane – Giess 2017). Example of all selected methods is seen in figure 5.

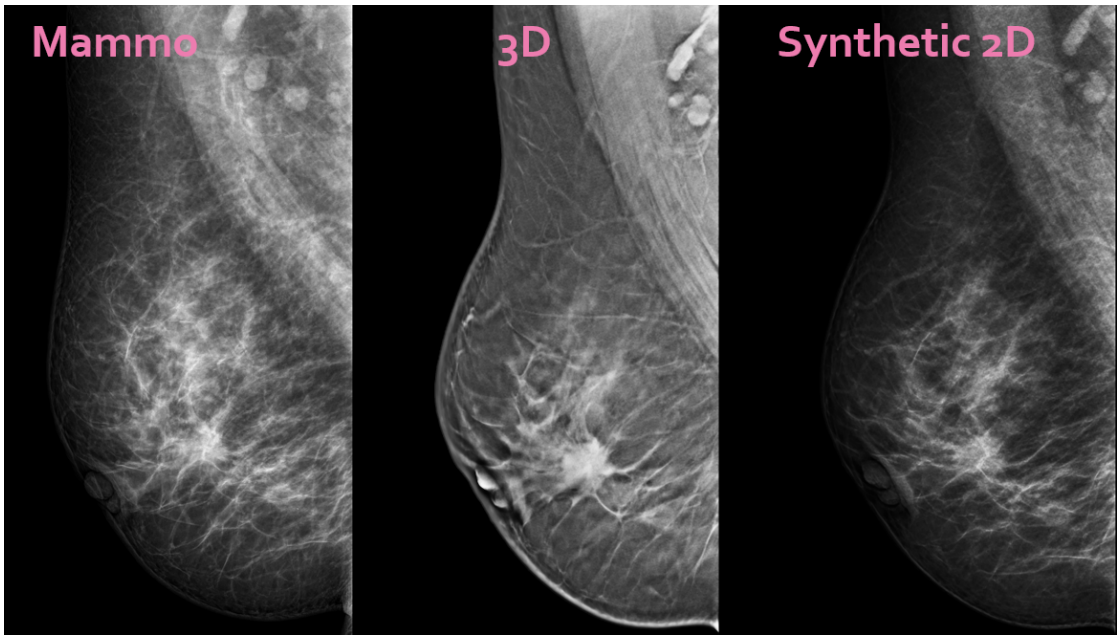

Figure 5. Example of all selected imaging methods. (Images courtesy of Dr Ferreira 2019)

4 E-learning

E-learning term was introduced in 1983 in a journal article by White defining it to be "*Learning via electronic sources such as television, computer, videodisk, teletext, videotext.*" (White 1983). Later electronic or e-learning was also defined to be interactive distance learning by Morri in an article from 1997. Computers had been used in education for a long time before the term, e-learning was introduced: Computer Assisted Instruction-concept (CAI) has been known since the 1960's and was used to teach problem solving (Zinn 2000).

E-learning is seen as the action of achieving information and knowledge using technology as a tool for the learning process (Aparicio – Bacao - Oliveira 2016). These technical tools, e.g. visualization and storage possibilities as well as communication and writing technologies, can be combined in e-learning systems. Aparicio, Bacao and Oliveira introduce in their article from 2016 the three key components of e-learning systems to be users, technology and services as illustrated in figure 6. (Aparicio – Bacao - Oliveira 2016)

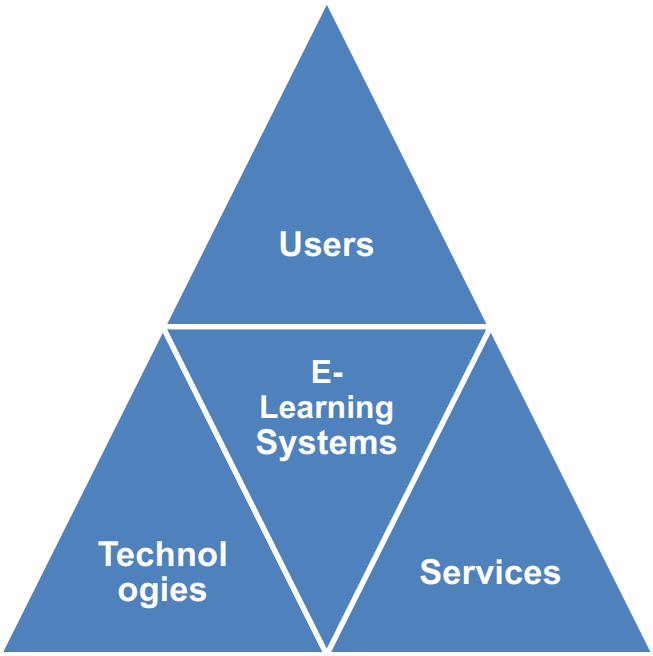

Figure 6. Theoretical framework of E-learning system (Simplified from Aparicio, Bacao, Oliveira 2016)

Users are defined to be the systems stakeholders, including customers, suppliers, board and shareholders, special interest groups and professional associations, which interact with the e-learning system. Technologies enable interaction between system and users, but also enables connections between different groups of users. This is done by making communication and collaboration possible as well as maintaining content of the system. The services implement e-learning activities to pedagogical models and instructional strategies. (Aparicio – Bacao - Oliveira 2016).

In the 1990s World Wide Web (WWW) was invented and this enabled new innovations and diverse possibilities to share information and be in contact with others (Vainionpää 2006, p35). E-learning is connected to online learning, that is considered when learning is happening partially or completely via internet allowing the participant to be autonomous regarding time and locations restrictions (Aparicio – Bacao - Oliveira 2016).

4.1 Online e-learning pedagogy

Online e-learning is an active and self-directed learning process. Because of this, e-learning has been connected with constructivism learning philosophy (Vahtivuori-Hänninen 2004 p11, Vainionpää 2006 p31-32). According to constructivism, learning is the

outcome of students own actions (Salminen – Suhonen 2008). In constructivism the gained new information is connected to pre-existent structures of knowledge and student adapts own actions according to e-learning solution. Constructivism in e-learning is shown in student independence and self-directedness (Vainionpää 2006 p31-32).

E-learning possess also some features from other learning theories. Entwining learning new things to students own previous experiences with e.g. using communication and realistic simulation solutions to help understanding the subject, can be associated to realism theory. Behaviourism theory can be seen in repeated task series, though this is rarely used with adult students (Vainionpää 2006 p31-32).

Online e-learnings role depends on how it is used in teaching. Learning in total can take place via online or only some parts of the learning process are online based and combined with other learning methods. Later solution with mixture of classroom learning and e-learning is called blended learning (Masie 2006 p22). Online services can be used just as means of sharing information to learners or they can be built to be a complete learning environment where participant activity is an essential part of learning process (Kimpimäki – Laitinen - Lohineva-Kerkelä, 2008 p144). In synchronous e-learning learning is real-time and involves online studies with aid services such as videoconferences or chats. This enables direct interaction with participants and teacher during real-time courses. Asynchronous e-learning can be done with participants being offline. Studies can be done in participants' individual pace and e-learning is used as a tool to support learning (Hrastinski, 2008).

There are four ways of using online e-learning solutions in teaching by combining the level and the number of technical features related to learning, e.g. mixing previous chapter possibilities. Online services can be used as a distribution channel of complete sets of learning materials, e.g. study books that requires self-learning from user. E-learning as a supportive service for other teaching methods means that it is used to provide materials that are used among other methods and alone are not complete study packages. Third option is to use e-learning to support traditional teaching methods so that user activity is transferred to online services where students can discuss, do related tasks and groupworks. In final possibility online e-learning services offer the complete learning via active learning methods and no other teaching methods are used (Kimpimäki – Laitinen - Lohineva-Kerkelä, 2008 p144). This is visualized in figure 7.

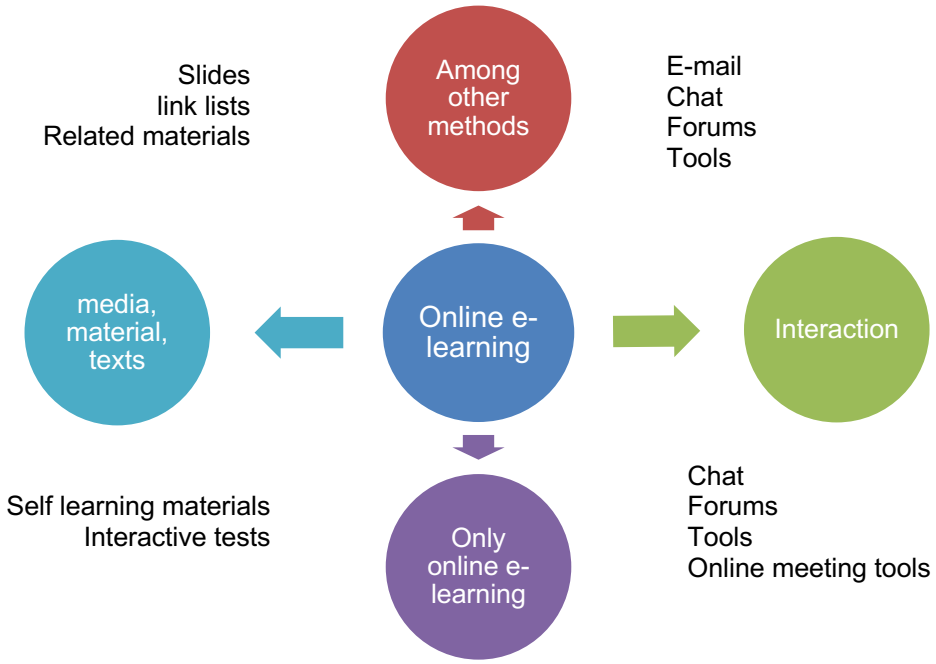

Figure 7. Using online e-learning in teaching (modified Manninen 2003 p29)

Key components of e-learning systems were described to be technologies, services and users (Aparicio – Bacao - Oliveira 2016). To be functional online e-learning portal needs well designed structure and content, but it also requires certain elements from users. To be beneficial portal for learning online e-learning services requires self-directing qualities such as independence, open mind set and curiosity as well as inner commitment and motivation from users. (Kimpimäki – Laitinen - Lohineva-Kerkelä 2008 p158) As well as these, the user needs to possess certain technical skills to be able to use and benefit from e-learning services (Leinonen 2008 p161).

Participants on online study courses have experienced e-learning as pleasant, diverse and beneficial. Advantage of e-learning is the autonomy regarded time and location restrictions. (Vainionpää 2006 p189-190). E-learning possibilities create new innovations and possibilities to update teaching methods and implementations (Leinonen 2008 p161). For them to promote and enhance sustainable learning the implementations need to be well-structured and organized (Leinonen 2008 p161, Vainionpää 2006 p189). The quality of e-learning solution arrangement is claimed to have impact on student motivation and student drop-out rate. (Vainionpää 2006 p189)

Online e-learning faces some issues and negative attitudes from systems stakeholders. One issue is the systems and learning environment building and maintaining costs. The

structure, methods and content in e-learning services needs to be up to date to interest users and enhance learning. This requires continuous improvement actions to content and methods as well as feedback gathering from users to maintain system. Resources (e.g. personnel and time) to achieve this should be considered and scheduled when constructing an online e-learning system (Kimpimäki – Laitinen - Lohineva-Kerkelä, 2008 p158-159). E-learning is not the only learning method that requires continuous improvement actions to be successful and efficient method, but these will apply to most learning methods as well.

Negative feedback related to online e-learning courses have to do with challenges in time scheduling, technical problems, feel of loneliness and loss of guidance, peer support and interactions with others (Leinonen 2008 p161, Vainionpää 2006 p48,189-191). Adult student variable with the level of technical skills needed to use e-learning. Lack of previous experiences can create prejudice and cautious attitude toward new learning possibilities. These issues can culminate and create anxiety and even inability act in online environment. Amotivation toward e-learning is seen when students feel that benefits gained from e-learning are minor compared to the resources needed to achieve smooth operation of the new system (Leinonen 2008 p161-170). These issues will decrease with time when the next generation of adult students emerge to use e-learning (Leinonen 2008 p161-170).

4.2 Benefits of e-learning in low-resource setting

One key driver to produce online e-learning solution is to be able to offer cost efficient and fast education solution. Implementing continuous professional education has been facing challenges in Finland because of limited financial resources and substitute employees (Harju - Risikko 2003). In rural areas interactive e-learning solution will help those radiologists with limited experience on novel imaging modalities and clinical cases to work with new features (Pratikakis - al 2007). This will enhance continuous education possibilities for professionals in low-resource areas and aid for fast, beneficial and safe use of the system. Already in 1999 Curran and Noseworthy were studying the possibilities to enhance healthcare professional continuous education in rural areas with e-learning and distance learning. The study identified that main issues on gain education were ongoing responsibilities related to work, travel distance and associated costs (Curran - Noseworthy 1999).

E-learning and computer learning has a long history, but it still is an evolving concept especially in present digitalization era with new possibilities and innovations emerging. Literature concerning e-learning is continuously expanding despite the present vast amount as well as the usage of e-learning systems globally (Aparicio – Bacao - Oliveira 2014). The ongoing digitalization and digital transformation will enable new possibilities to emerge continually to enhance our every-day life and healthcare. High-income countries have advanced in digital services for years, but many of the least developed countries are waiting to be able to benefit from new technologies that can enhance the possibility to receive healthcare and social services, improve treatment prognosis and increase the level of professional education. E-learning is connected to internet access and United Nations - UN is committed to make affordable internet access available to all countries by 2020 (UN 2015). This requires that mobile network infrastructure is built to cover also the least developed countries, device costs should be close to local economic means and the needed technical skills should be promoted for people to benefit from universal internet access (ITU 2018). These key components of universal and affordable internet are presented in figure 8.

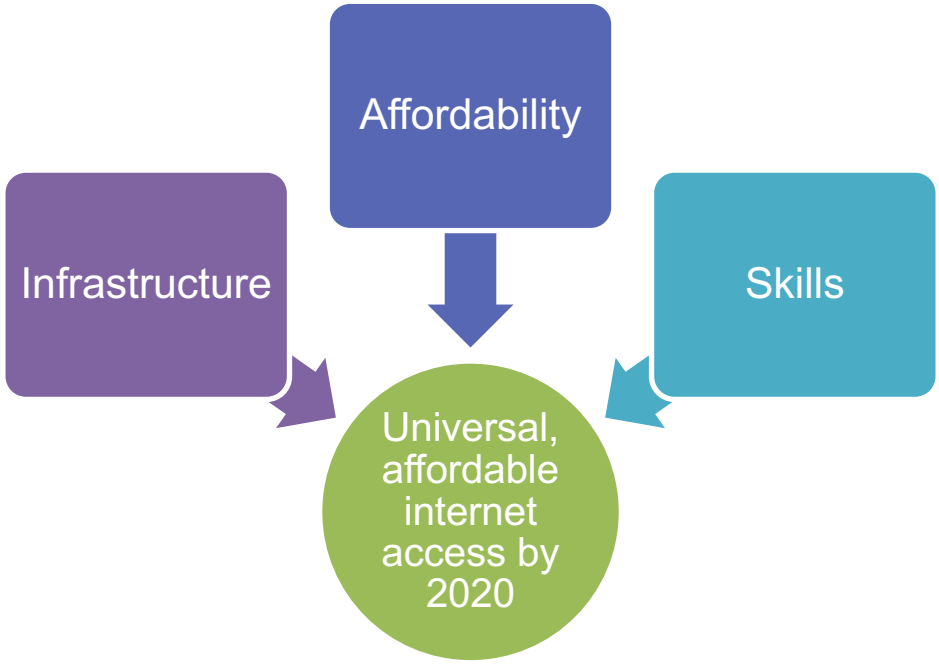

Figure 8. Key components of universal and affordable internet (ITU 2018)

Easy access to internet combined with smart device price decreasing allows mobile technologies to aid e-training possibilities in least developed countries. This combined with cloud-based information and data storage systems and overall digitalization will promote

professional collaboration and global information sharing. Increased e-learning possibilities will help to meet up with the World Health organization's (WHO) estimation of global need for 12.9 million additional health professionals (Mayes - White 2016).

5 Ways to learn

People learn in different ways: some adapt most knowledge *visually* by watching and drawing as well as relying on photo memory, others are *audiotivity* persons who gain information from hearing and *kinetic* learners require actions and feeling things to absorb knowledge. Some people possess combination of these three ways, e.g. some are audio-kinetic learners (Järvilehto 2014). Content and methods used for teaching should contain several means and ways to deliver the same information to promote sustainable learning of all kind of individuals.

Learning is most efficient when it is pleasant. Many studies have been made on the association of learning styles and effectiveness of different types of learning types of e-learning (Doulík, Škoda & Šimonová, 2017), (Liu, Peng, Zhang. 2016), (Noesgaard, Ørngreen 2015), (Ruiz, Mintzer, Leipzig 2006). People with different background, age or culture can achieve impressive outcomes when they are learning via playing games, gaining information from different sources and seeing interesting films. Learning doesn't need to be serious and it can easily include passion, commitment and concentration and flow. As seen in figure 9 efficient way of learning is introducing content in an inspiring from to the participant who possesses interest in the topic (Järvilehto 2014).

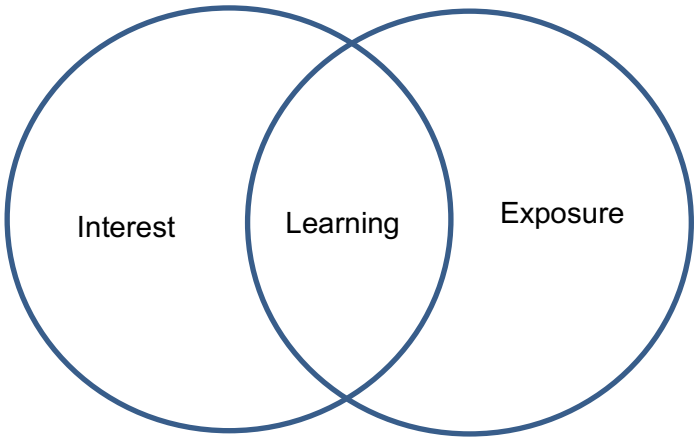

Figure 9. Learning consist of interest and exposure. (Järvilehto 2014, s.62)

Sustainable learning is the combination of pre-existing interest to the subject and exposure to inspiring related material. Key factors of efficient learning are intrinsic motivation, growth mindset and achieving flow-mode when studying. (Järvilehto 2014)

5.1 Types of motivation

One of most important elements needed to activate and enhance sustainable learning is motivation. Without motivation there is no actions at all, and this can be seen in unwillingness. Participants must have or create a need, understanding or reason for the actions that are expected from them to successfully fulfil task and reach goals. If the learner possesses active personal commitment to the task it is shown to enhance persistence, increase positive self-perceptions, and improve engagement to matter (Järvilehto 2014).

According to article by Ryan and Deci from 2000 there are three types of motivation as seen in Table 1. The types of motivation are amotivation, extrinsic motivation and intrinsic motivation.

Table 1. Motivation type taxonomy (simplified from Ryan - Deci 2000a)

Motivation styles	**Amotivation**	**Extrinsic motivation**	**Intrinsic motivation**
Associated styles	• Nonrelevant • Nonintentional • Low competence gain	• Compliance • Approval • Goals • Congruence	• Interest • Enjoyment • Satisfaction
Perceived locus of causality	Impersonal	External to Internal	Internal

Amotivation, where the willingness to act is missing, can be seen as unwillingness to act. This means that no actions are done or only done by force without any intent. Reasons for amotivation can be that there is no value in the action itself, there is no competent feeling of doing the action or any kind of desired outcome related to the action is missing. **Extrinsic motivation** or external motivation is actions that are done because of external reward is expected, to fulfill others' needs or request or to gain goals. Doing actions with extrinsic motivation may differ in relative autonomy from external reason to internal reason and lack the enjoy of action: For example, an employee doing tasks because managers demand things to be done (external regulations) versus employees doing tasks because they have a promotion as a goal (internal regulation). In **intrinsic**

motivation or inner motivation, the actions are made to fulfill own psychological needs and to gain satisfaction from the activity itself. Things done with intrinsic motivation are actions of self-determination and will improve well-being. (Ryan - Deci, 2000a)

According to Ryan and Deci intrinsic motivation can be reduced by tangible rewards because they start modifying the internal motivation to extrinsic motivation. Task deadlines, orders from others, evaluations with pressure and set goals have the same effect to inner motivation as tangible rewards; they mold it to extrinsic motivation by decreasing the feel of autonomy. On the other hand, features that improve autonomy such as freedom of choice, emotion recognition and possibilities for self-directing have proved to improve intrinsic motivation. (Ryan - Deci, 2000a)

5.2 Psychological needs

According to Niemiec, Ryan and Deci and their study from 2009, intrinsic motivation enhances person well-being and psychological health by satisfying to our basic psychological needs. Actions made due to extrinsic motivation in the contrary had no or negative affect to psychological health. Fulfilling these psychological needs is important as they enhance ones' inner motivation and activate personal commitment, thus enhancing learning. (Niemiec - Ryan - Deci, 2009)

In an article "Self-determination Theory and the Facilitation of intrinsic motivation, social development, and well-being" from 2000 by Ryan and Deci, stated three main psychological needs that are autonomy, competence and relatedness. When we are able to satisfy these needs, we enhance our happiness and well-being, and this reflects to sustainable learning. In the next three chapters these three main needs are explained. (Ryan - Deci 2000b)

Autonomy is the feel of freedom, the idea that one can affect and change their life with their own actions. These actions are not controlled or restricted by other people's actions or needs. Järvilehto states in his book that autonomy enhances cognitive actions, well-being and learning. Freedom as a term might not be related to autonomy. The idea of autonomy is more focusing to the ability to have effect on own life and the feel of self-directing within the present limitations that might be. Autonomy is built from mindset and abilities to take responsibility from own actions and see those actions as own. (Järvilehto 2014 p29-30)

The second defined psychological need is competence that Rigby, Ryan and Przybylski define in their study from 2006 as a need for challenge and feelings of effectance. Competence can be understood as the ability to get challenging and interesting tasks done and reach goals to produce valuable results. When we face challenges and overcome them, we also evolve in those actions we did (Rigby, Ryan, Przybylski, 2006). Feeling competence requires work and effort, this is why you seldom get the satisfaction from easy tasks. Reaching pre-defined goals usually gives just a momentary feeling of happiness, but if the task itself is rewarding, it will grand a longer effect on well-being. This is because of the feeling of competence comes from exceeding own capabilities and achieving new knowledge and skills. We should challenge ourselves to tasks that are challenging but not impossible. (Järvilehto 2014, 31)

Third need related to improved motivation and well-being is relatedness that is the need to be connected to others. People naturally seek to be in contact with others to create meaningful connections and to feel part of a group. Efficient learning method is to share gained knowledge with others and to be able to discuss to achieve others perspective on the matter. Previously mentioned autonomy and competence are needs' that one can fulfill by themselves, thus experience of relatedness is something that often requires someone or something else to attend. (Järvilehto 2014 p33-34)

According to Järvilehto, autonomy, competence and relatedness supports one another, and they create a circle of positivity: autonomy helps to find new challenges that enable feelings of competence. Competence increases possibilities to affect the society and society is willing to invest resources to these actions with positive results, thus enabling more autonomy. If these psychological needs are not fulfilled, sustainable learning can be challenging to achieve states Järvilehto. E-learning solution services should contain methods and tools to promote autonomy, competence and relatedness of the user. These services are the pedagogical models and instructional strategies that were stated as main components of e-learning systems according to Aparicio and al. in article from 2016 (Aparicio – Bacao- Oliveira 2016).

6 Available e-learning solutions for image interpretation

As written earlier White defined e-learning to be: "*Learning via electronic sources such as television, computer, videodisk, teletext, videotext.*" (White 1983). Using e-learning possibilities in medical and healthcare education has increased rapidly during the past decades (Liu – Peng - Zhang 2016) (Ruiz – Mintzer - Leipzig 2006).

Several mammography system manufacturers offer their own solutions for modality training. This includes on-site trainings that are held at the customer site by bringing consultants and application specialists and, if needed, the training data set of breast examinations to the facility (Hologic 2017). Data set containing clinical images for training purposes is transferred to clinics PACS (Picture Archiving and Communication System) or locally to Review Workstation (RWS) to enable clinical examination of the images. Real patients can be used real-time for training purposes if they are applicable at the time of training (Hologic 2017). System manufacturers offer interesting learning material for free on their websites to promote self-directed learning (Hologic 2019). These are usually promotional material at the same time done via Key Opinion Leader (KOL) -networks of manufacturers and customers. Despite this collaboration this material offers various resources of information from selected researches of product and clinical operation presentation videos.

Exhibitions, conferences and seminars are combined with various possibilities to attend imaging modality trainings (RSNA 2018) (ECR 2019) (EUSOBI 2019). These include lessons, workshops and research presentations held in auditoriums where participant participation is mainly focused on listening, making own notes and participating to possible discussion after presentations. Due to time restrictions the discussion part at the end of the presentation or lessons can be relatively short for learning purposes.

Workshops are intense learning events or programs that are focused to improve skills and techniques in a certain matter or subject. They are usually brief and intense courses for relatively small group of participants. Often required tools and materials are offered onsite to participants (EUSOBI 2019). Hands-on workshops and theoretical information sharing via lectures are often combined to create course content to provide throughout overview of the topic (EUSOBI 2019). On-site and conference trainings are efficient with creating the feel of competence and relatedness, but they are low on participants autonomy when considered time and location restrictions. These solutions can be expensive

with costs containing staff requirements, event arrangement, locations fees and the lost resources of people needing to be away from work and social situations (Harju - Risikko 2003).

Apart from system manufacturers there are third party learning service providers. One of these is Mevis Online academy services that offer an interactive learning platform that is configurable according to customer preferences and needs (Mevis 2018). The service is directed to manufacturers and institutes to support radiology training possibilities and it supports several imaging modalities: computer tomography (CT), magnetic resonance imaging (MRI), ultrasound, positron emission tomography (PET), computed radiography (CR) and mammography including tomosynthesis. Business customer can define needed tools for learning, built exams for users and provide data sets containing clinical cases and supportive learning material to be transferred to portal. Mevis online based service is accessed with username and password from any computer and web browser without hardware or software installations (Mevis 2018).

In 2018 an open access education and training portal was launched called EBreast. It is dedicated to offer training in early detection of breast cancer for all health care professionals that are involved in the service chain of breast cancer detection. Collaboration of institutions from Finland, Norway, Portugal, Estonia and Switzerland formed three e-learning modules based on study results that are replying to the issues radiographers identified in mammography training and clinical practice. According to the study radiographers most common challenges in clinical mammography were seen to be technical performance, patient centeredness and quality issues in practices (Metsälä – Meystre - Jorge - al 2017). First module of E-breast includes topics of early breast cancer detection and diagnostic procedures. Second module focuses on breast screening, imaging and quality assurance. Third one concentrates on new imaging and laboratory possibilities and further imaging. E-breasts main target is to improve co-operation between different professional groups related to breast cancer and enhance services in breast imaging process by using interprofessional education approach and offering articles with on time information from recent studies and literature reviews. It will also help to harmonize mammography practices and education in Europe. (EBreast 2018)

7 Research methods

In this qualitative research thematic interviews were used to gather information from experiences and opinions of Finnish breast radiologists about e-learning portal content and learning activities according to their previous knowledge and experiences on modality trainings. Interview participants were considered to be experts of the subject matter and possess relevant information about it. Theoretical background information was gathered from breast imaging modalities, e-learning and e-learning pedagogy to improve understanding of the topic.

During theoretical background collection, it came to view that there are several possibilities to teach and learn new breast imaging modalities via e-learning. What was not found during the theoretical background search, was the individual opinions of radiologists about learning new breast imaging modalities and how it should be done. To obtain this information thematic expert interviews were considered to be best method. Focus group discussion was considered as one possible method but it was not selected because of limited time resources and arrangement challenges. Structured interviews were seen too strict for the subject and were not used with the risk of missing some usable information.

7.1 Sampling

In qualitative research the main aim is often not the statistically proven generalization of the subject, but the aim is to describe a certain phenomenon. Because of this it is seen essential to select participants that possess experience and information on the research subject (Tuomi – Sarajärvi 2018 p97-98). This statement was guiding the selection of sampling method of the research.

In this study purposive (non-probability) sampling was used to invite expert attendees to participate to interviews. Purposive sampling is typically connected to qualitative researches when it is desired to select units to participate that are directly related to research questions (Bryman 2008 p375). This sampling method was suitable because this study and the research questions aimed to find out opinions of radiologists who had previous experience on breast imaging and had been working with new breast imaging modalities. This selection was to make sure interviewees were recently trained to use a novel breast imaging modality.

Suitable candidates for the interview were collected from researchers' personal network built from various previous experiences related to past educational situations and professional employments. All interview participants were connected and were participating to interviews as a private person and they were not representing ideas and or opinions of their present employers. The interviews were only focusing on interviewees' individual and personal experiences and they were not related to participants' employer. All participants gave their verbal consent at the beginning of the interview and signed an informed consent form.

The sampling frame is seen in figure 10. Radiologists with no experience on mammography or breast radiologists with no tomosynthesis experience might not possess the information needed to this study nor interest and motivation to attend to interview. To gather relevant information from motivated participants, breast radiologists with known experience in new breast imaging examinations were contacted by email inquiring willingness to participate to interview with information letter (Appendix 1) attached. During invitation phase the invitation letter was updated to a clearer and more informative format. The updated invitation letter is seen in appendix 2.

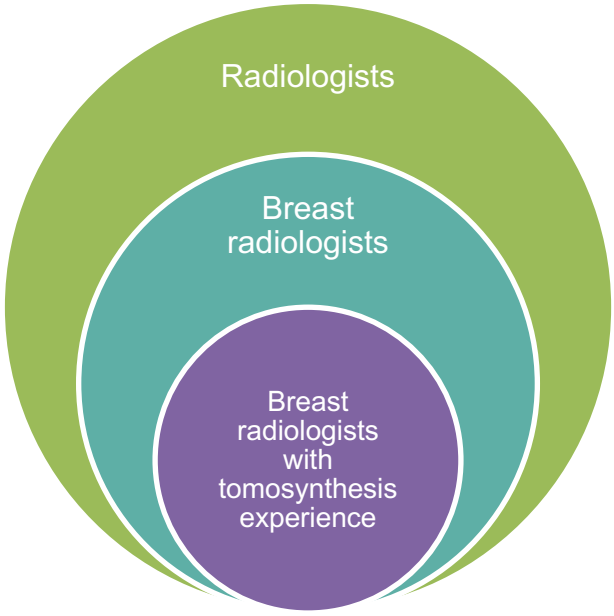

Figure 10. Sampling frame of the study

Interviewees were also recruited via snowball sampling, also called network sampling (Burns, Grove 2005) by asking from initial interview participants that were known to be

relevant to the topic to recommend other suitable radiologists with required experience on breast radiology to participate (Bryman 2008 p184-185) (Tuomi – Sarajärvi 2018 p99).

With snowball sampling there is a risk of sampling bias because participants may recommend acquaintances who might possess similar mind set with the original participant. There is risk that human judgement affects the selection and some persons from the suited population are more likely to be recommended and selected compared to others (Bryman 2008 p169). In this study the first attendees were selected with different key characteristics, such as the level of experience, working places, background, and were contacted directly by the researcher via email and information letter. This was done to minimize the possible distortion of interviewee representativeness, that might have been possible with by using only snowball sampling.

Seven original invitations were sent in the beginning of interview recruitment. Four of these were willing to participate. During first interviews participants were asked if they knew suitable colleagues who would be willing to participate as well. According to gained contacts five more interview invitations were sent. From recommended and contacted contacts one interview was planned. Sample size was total of five.

Interviews were done close to the theoretical saturation point of the data balanced with the human and time resources available at the time from the researcher. Theoretical saturation point means that there is no new information gained from new interviews and the concept is fully explored (Bryman 2008 p416, 542). Interviews started to produce same information and theoretical basic pattern was revealed with five interviews done (Tuomi – Sarajärvi 2018 p99-102). There is a possibility that more interviews could have brought individual experiences related to suggested content and methods for e-learning solution. Researcher considered that the collected data from five interviews was sufficient for this thesis.

Thematic interviews were made with three main topic questions presented to the interviewees during the interview discussion. The questions were: How have you been able to learn new breast imaging modalities before? What methods of learning have you seen to be the most beneficial to learn new breast imaging modalities? What kind of content suits best to teach novel breast imaging modalities? Between these main questions the interview discussion was allowed to flow on its own. Researcher was able to guide the discussion back to main topic if the interview started to wonder away from relevant topics.

7.2 Data collection

Data was collected during January 2019. First interview was held on 9th of January 2019 and the last on 28th of January 2019. Total of five interviews with suitable breast radiologists were scheduled. Participants varied from each other on level of experience, working places, background and geological location. Average age of interviewees was 51,8 years and three of the five (3/5) participants were females. Average experience as radiologist was 18,6 years and as breast radiologist average 15 years. All 5 radiologists were either currently working with tomosynthesis or had gained tomosynthesis experience via training. Average interview duration was 30 minutes. Transcribed interviews were 34 pages in total with font size 11 and line spacing 1,5.

At the beginning of the interview the interview themes were informed to participants as well as the introduction to research was discussed. Interviewees were reminded that participation was voluntary, and they could cancel their participation at any state of the study without a reason. Participants were asked a permission to record the interview and all agreed. They were informed that all personal data was to be removed from the interviews and transcripts and possible quotations in written report. Only the interviewer would know the identity of interviewee participants. Participants were told that interview recordings were to be transcript to a written format to help data analysing. All interview data was informed to be deleted at the end of 2019 and stored until then in password secured location. All interviewees agreed to these terms. At the end of the interview every participant were asked if they could be re-contacted by the interviewer if there would arise further questions about the matter or something was not clear from the recorded interviews. All participants agreed and gave their consent.

Interviews were made face-to-face or via phone call. Four of the interviews were made face-to-face and one via phone call. Phone call interview enabled wider geological coverage of the participants and resource savings in time and travel expenses from both interviewer and interviewee. Phone interview was more challenging on rapport building and probing for the interviewer. Rapport, meaning a relationship that encourages collaboration, is important to achieve between the researcher and the participant to enable informative interview. Though rapport is balancing in a fine line because lack of it can cause unwillingness to participate or terminate participation and too much of it may delay the time of interview and mold the replays to please the interviewer. (Bryman 2008 p201-202)

To build rapport every interview was started with introduction of researcher and the topic. Keen eye contact, smile, handshake and brief small talk were used to ease the situation. Interviewees were given the change to decide interview location and time so that they would feel the most comfortable to attend. Building rapport in face-to-face interviews is considered easier than interviews done via phone, because latter is missing the visual possibilities of friendliness such as smiling and eye contact (Bryman 2008 p201-202).

Probing is common part of interviews when researcher encourages the interviewee to give more information. Because research interviews were thematic with open ended main questions to guide the discussion, probing was not considered causing bias to gathered data (Bryman 2008 p206). Probing is more commonly problematic when doing structured interviews and the interviewer needs to make an intervention to aid respondent to give more information. This may influence interviewee and their responses and thus cause an error to data Probing was seen challenging by the researcher during the first interviews. This was mainly because of researchers limited interview experience.

If open questions didn't seem to inspire enough information from the participants, some standardized probes were used during interview, e.g. asking for more information or encouraged them to continue with smiling and other facial impressions. For the first interviews it was difficult to see the need for probing, sometimes just a brief silent moment could have worked for the participant to continue talking. It requires good and fast character recognition to be able to give participants the time they need to process interview topics and start replying naturally.

Main data from the interviews were the recorded interviews and the transcripts made of them. During interviews some minor field notes were made, but this was seen challenging and time consuming by researcher. Writing filed notes during interview seemed to cut the connection to interviewee. This was seen as disadvantage and was considered to have had an effect on the created rapport. It was seen more informative to connect with the interviewee and to maintain good rapport and keep probing, than writing field notes during interviews.

7.3 Analysis method

Data from interviews was handled with systematic qualitative content analysis with inductive approach (Bryman 2008 p539). This is a three phased process that is formed from data reduction, data clustering and forming theoretical concepts. First the unit of analysis was defined according to defined research questions to guide the content analysis (Tuomi – Sarajärvi 2018 p122-123). The unit was set to be learning new breast modalities.

The analysis process is visualized in figure 11. Interviews were recorded with mobile application. All interviews were transcribed from audio to a text form and printed out to a paper. Interviews were listened and read though several times to gather throughout understanding of the data. Then the transcript interview data was reduced to condensed meanings that were related to the unit of analysis.

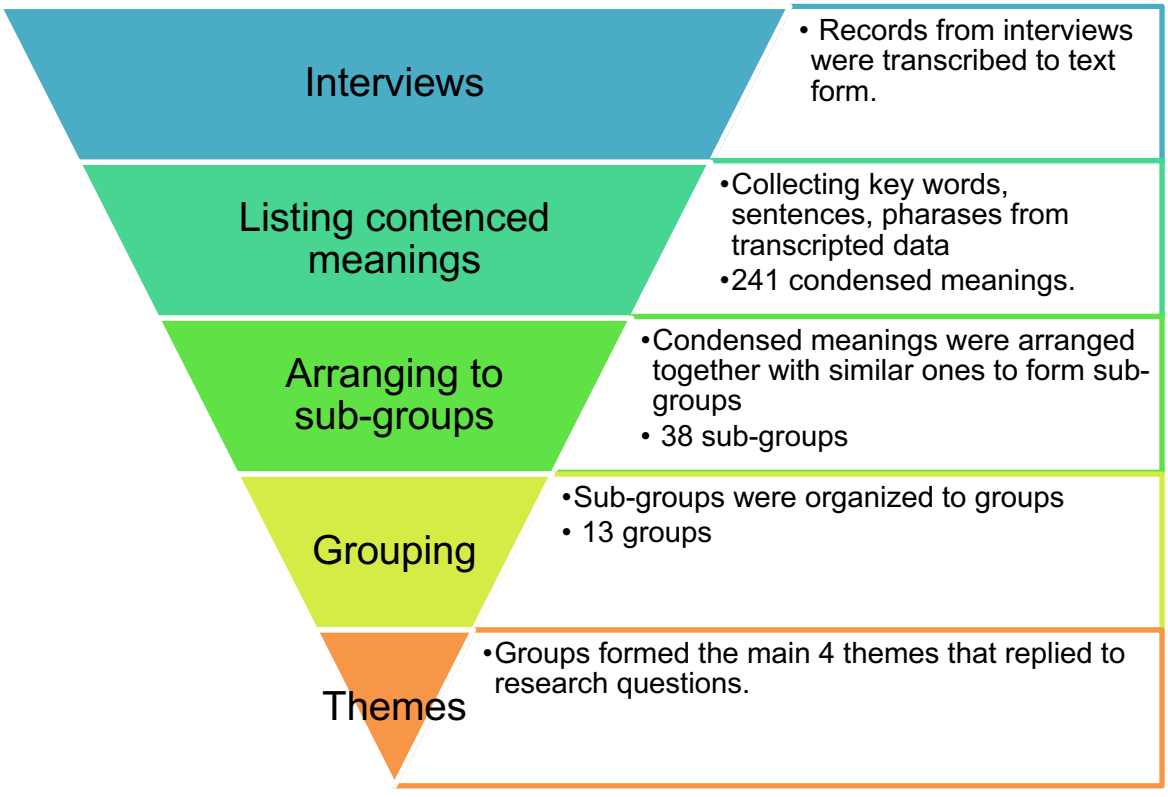

Figure 11. A systematic qualitative analysis of the interview transcripts visualized

A list of condensed meanings was collected from meaningful points such as key words, sentences and phrases from the data that were related to research questions. Condensed meanings were organized to sub-groups and they were furthermore arranged to

groups and finally to themes that corresponded to the research questions. During analysis 241 condensed meanings were collected from the interviews. These formed 38 subgroups that were arranged to 13 groups and to 4 themes that were answering to research questions.

8 Results

Interviews brought up similarities and some individual experiences about radiologists' experiences on learning new breast imaging modalities. Transcript interview data was reduced to condensed meanings and they were clustered to sub-groups and groups finally forming four main themes that replied to research questions.

According to research data new information on novel breast imaging modalities are mainly gathered via self-directed information gathering, dedicated courses and workshops as well as lectures in conferences and system manufacturers' demonstration about their products and/or new innovations. Even though attending to these events were seen to build basic understanding about features of the modalities, it was seen that discussion about the topic with colleagues and working with new modalities were the most important methods of gaining experience and improving knowledge on new breast imaging methods. Reflecting abilities of the new modality to previous imaging modalities and to radiologist own knowledge of breast diseases was beneficial from learning perspective.

For the first research question: What kind of content is needed for the e-learning solution? Main themes according to data analysis are content for modality introduction and clinical content for modality implementation. For the second research question: "What kind of learning methods should be implemented to e-learning portal?" Main themes formed to be active learning methods and passive learning methods.

Modality introduction content- theme is built from groups system introduction, academic information and technical section. *Clinical content*- theme formed from interesting and variable clinical examination data and clinical implementation guidance. *Passive learning method* was seen beneficial for introduction and overview of the topic by user self-directed learning materials. Material should include same information in various forms to promote understanding by different types of learners. *Active learning methods* with social

interactions, were seen to be efficient to enhance deeper understanding and implementing knowledge of new imaging modalities. Social connections, discussion, practical training on clinical setting, as well as teaching others and knowledge testing was seen suitable methods to implement knowledge.

8.1 Content

According to data analysis the suitable content to implement to e-learning solution was divided to two themes: content for modality introduction and clinical content. The themes can be further divided to groups and sub-groups seen in figure 12 and figure 13.

8.1.1 Content for modality introduction

To gain introduction to the modality and standard level knowledge of the topic, material related to system introduction, related academic information and technical section were seen beneficial. Modality introduction content analysis is visualized in figure 12.

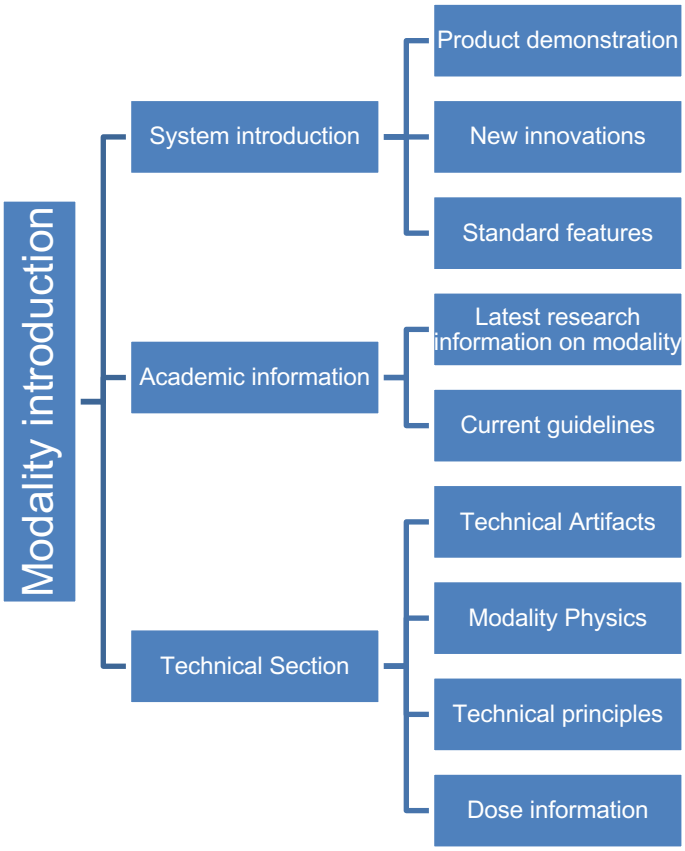

Figure 12. Modality introduction-theme, groups and sub-groups visualized.

System introduction content includes product demonstrations and explaining new product innovations and standard features of the system. These are seen beneficial when building the base understanding of product and modality. Interviewees stated to meet product manufacturers in international conferences and in technical exhibitions where product demonstrations are possible.

Academic information containing modality related research information and pre-existing data on current guidelines were stated to be beneficial to get a reliable overview of the modality use and understand the implementation possibilities for clinical setting. Interviewees stated that they actively follow literature and new publications on breast imaging field and share information with colleagues about newest trends.

> Meillä pitää olla asioista tietämystä, et niihin perehdytään... Mutta luetaan artikkeleista ja mietitään, mikä vois parhaiten meille toimia. (Interview 4)
>
> We need to have knowledge, that's why we look in to them… We read articles and consider, what would best suit us. (Translation by researcher)

Technical section was seen beneficial to be included to content. Topics of this section would be modality dose information, technical principles, modality physics and technical artifacts. Basics of these was noted to be standard information that is required to know by radiologists. According to interview it is important to be able to differentiate technical artifacts from possible real breast findings.

> Kyllähän (tekniset) perusteet toki tarvitsisi tietää. Että tietää virhelähteet. Ainakin magneetissa on kaikenlaista virtalähdettä, mikä voi voi tuota…. en nyt osaa heti sanoa mitään selkeitä. mutta täytyy sen magneetin ominaisuudet tuntea, että tietää et joku löydös ei välttämättä ole totta vaan on virhelähde. (Interview 2)

> Technical basics should be known. To be able to know related artifacts. At least in MRI you have all kind of artifacts that can… But you need to know the technical features to understand that some clinical finding might not be actual but because of an artifact. (Translation by researcher)

8.1.2 Clinical content for modality implementation

E-learning solution content should possess clinical material to aid advanced learning and help clinical integration of the novel modality. Clinical content analysis is visualized in figure 13.

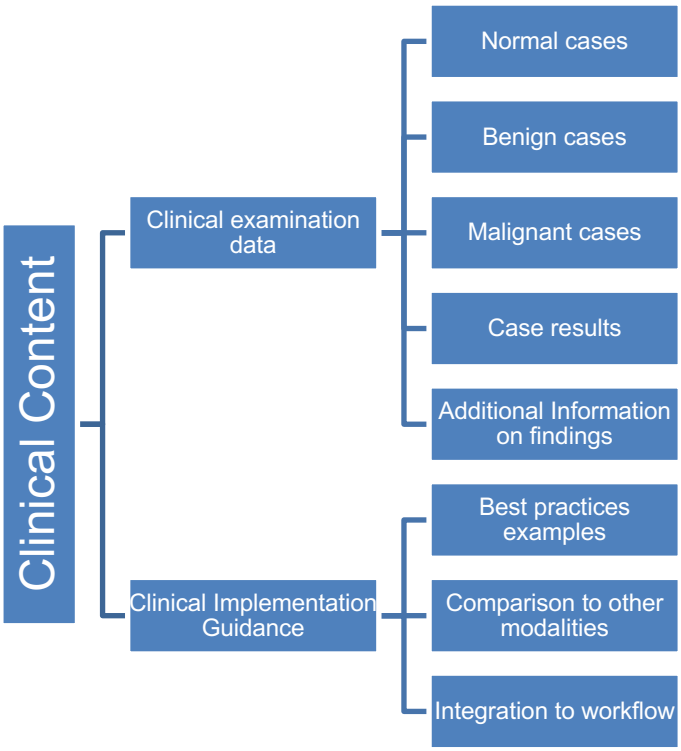

Figure 13. Clinical content-theme, groups and sub-groups visualized.

Most relevant content according to interviewees were realistic clinical examination data consisting of patient examples with verified diagnosis and additional imaging data. A set of clinical cases including normal cases, cases with benign findings and malignant findings were considered to be well suited to produce a basic understanding of finding visibility with new imaging modality.

> Potilastapaukset ovat sitten taas, jos haluaa syventää tietoa johonkin tiettyyn asiaan. Silloin saa vähän paremman käsityksen, miten tämä ihan oikeasti toimii. (Interview 5)

> Patient case are good, when you want to deepen understanding to a matter. You gain better understanding how it really works. (Translation by researcher)

The amount of cases can be relatively small if every case is attached with related information about the clinical status of the case and additional material of the possible related benign or malignant finding e.g. additional imaging modality data and literature.

> No ideaalista kerron: Minä olin yhdessä koulutuksessa, se oli ihan tavallinen workshop ja jokaisesta löydöksestä oli kirjallisuutta, mihin voi perehtyä. Tämä oli mainio, koska se on ihan valmis paketti. Koska aina sinä teet searchia, jos haluat jotakin selvittää, mikä se on ja mitä kirjallisuudessa asiasta on. Mutta tämä on jotenkin valmis paketti. …mutta se oli mainio, aika hyvin tehty, koska siinä oli sekä että: Kun katsot kuvan sinulle jäi mieleen ja oli vielä kirjallisuusluettelo, mistä sai tietoa. (Interview 1)

> Let me tell about an ideal case. There was this one training, basic workshop and each finding had additional reading information. This was nice because it was a well package. Because you always do research if you want to know more what is it and what additional information is there. But this was complete package…It was good and well made because you had both: You see the image and you'll remember it and you have the literature list for more information. (Translation by researcher)

According to interviews every case of the clinical examination dataset should be attached with correct clinical status and that no cases are left without this information. If student is unable to get correct feedback and information, this can have a negative effect to student motivation and thus, lowering the learning outcomes.

> Mutta se oli jotenkin vähän haastavasti sillä tavalla, että siellä ei käyty kaikkia läpi, vaan ne mitkä oikeasti oli sitten todistettu. Että jos joku kohta oli ollut semmoinen, että minä muistan yhden - Minä olin niin varma, että siinä on semmoinen piilotteleva syöpä ja sitten sitä ei käyty ollenkaan läpi. Minua harmitti jälkikäteen... (Interview 2)

> But it was challenging because not all cases were discussed, only the ones with clinical results. I remember one case- I was so sure there was a hidden cancer and that case was not discussed at all. I was irritated afterwards …" (Translation by researcher)

Clinical implementation guidance was seen beneficial to be part of the content. New breast imaging modalities might have challenges to fit into existing clinical habits. Information from experienced pioneer users can aid and accelerate integration for new modality. Content on modality integration to workflow, information of modality comparison to other breast imaging modalities and examples of best practice could accelerate the clinical use.

> …on ollut vaikeuksia löytää semmoista protokollaa, missä sitä (tomosynteesiä) käytettäisiin, nii et sanottaisiin, et aina nämä kuvataan tomolla tai aina nuo tapaukset kuvataan tomolla. (Interview 5)
>
> …it has been challenging to find a protocol to implement it, so that all certain cases would always be done with tomosynthesis.(Translation by researcher)

8.2 Learning methods

According to data analysis the suitable learning methods to implement to e-learning solution was divided to two themes: passive learning methods and active learning methods. The themes can be further divided to group and sub-groups seen in figure 14 and figure 15.

8.2.1 Passive learning methods for modality introduction

To gain introduction and good overview of the new breast imaging modalities radiologists informed in the interviews to read literature, attend lectures in conferences and see manufacturers product demonstrations and example images. Dedicated breast imaging courses were stated to include clinical case images and self-testing by marking findings from example images to forms. Some radiologists also actively follow new literature to gain information on newest trends on medical imaging. All radiologists informed that gained new knowledge is reflected to pre-existing experiences. From these sub-groups formed main groups of visual information, auditive information, audio-visual information, kinesthetic information and internal process. Passive methods analysis is visualized in figure 14.

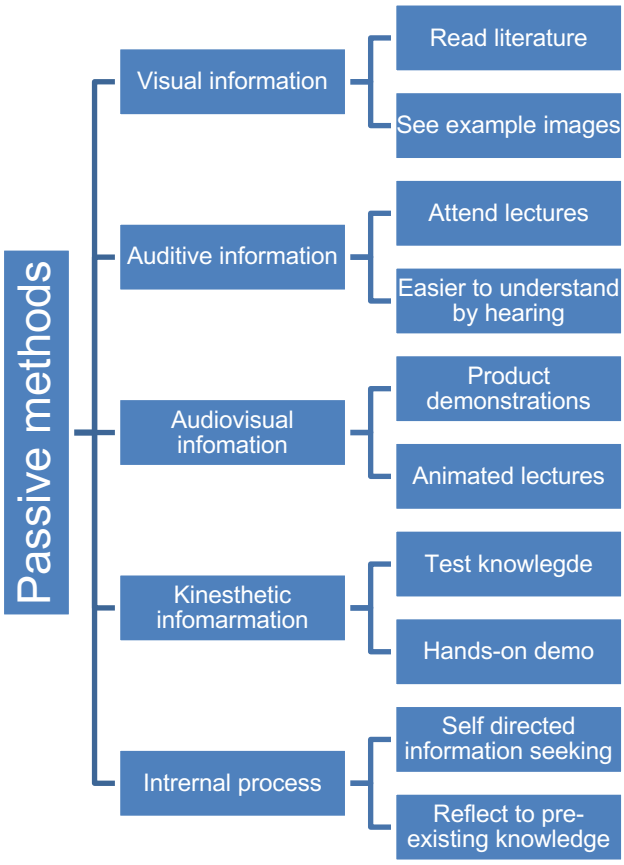

Figure 14. Passive methods-theme, groups and sub-groups visualized.

Introduction and overview of the new topic can be achieved with passive learning methods that also promote autonomy of the student. These can be reading and listening materials by self-directed learning. To build knowledge and understanding of a new imaging modality a set of written articles as well as article abstracts, spoken lectures and audiovisual demonstrations about basics information of the new modality was seen suitable method.

> Luennot on tuommoisissa parhaita, jossa esitellään uutta asiaan. Siinä se on pureskeltu valmiiksi ja joku on miettinyt asiat, mitkä on tärkeimpiä, mitkä tuoda esille. (Interview 5)
>
> Lectures are best, when introducing new matter. Information has been digested and someone has considered the most important matters to present. (Translation by researcher)

Full articles were seen somewhat challenging and full-work to be read by some. Some interviewees stated that they adopt information easier when listening compared to reading. Article abstracts, or lectures were seen preferable option because of these.

> Ainakin minulle se on helpompi, minä omaksun sen helpommin, jos kuuntelen selitystä. (Interview 1)
>
> At least for me it's easier to adopt information if I listen to explanation. (Translation by researcher)

The learning portal should contain same learning content in different forms to promote learning and make it interesting for most users. This can be done with article abstracts, audiovisual demostrations and video recorded lectures containing the same information and delivered in different forms to promote content adoption by different types of students. Trainings and conferences enable hands-on product demonstrations and sessions where participants are able to gain information via audiovisual and kinesthetic learning.

> Rinta-ct:stä olen saanut jonkin verran makua noissa kansainvälisissä konferensseissa, missä sitä on esitelty, mutta sekin on vaan demo-luonteisesti ja kuvia näytetty. (Interview 4)
>
> Breast CT has been introduced to me in international conferences where it has been presented, but this was just a demonstration and example images were viewed. (Translation by researcher)

According to interviewees self-testing was done in workshops and dedicated breast imaging courses with clinical cases, where cases viewed either alone or in teams and results were marked to personal forms and discussed afterwards. Testing the gained knowledge with questioners can be considered as a form of information sharing.

Lectures and abstracts should be well built and done with high quality – to improve learning, participant commitment and arise interest. They should also be realistic with up-to date information. Content of the lectures should not overly enhance the benefits of presented new modalities and they should not have association to commercial collaboration to be trustworthy.

> Riippuu, kuinka hyvin luento pidetään. Se on taitolaji. Osa pitää niin huonosti, ettei siitä jää käteen mitään. (Interview 4)

> It depends how well the lecture is presented. Some do it so bad that nothing is gained. (Translation by researcher)

8.2.2 Active learning methods for implementing clinical knowledge

To gain deeper understanding of the topic active learning methods were stated to be important. Interactions with others such as discussion of the topic, participating to social events and information sharing are suitable methods to gain new knowledge according to interviews. Implementing new modalities to clinical work with simulated training, expert training and practical training with patient were stated to be essential in gathering experience and understanding. Teaching others was seen to reform the gained understanding and prevent from getting fixed to old habits. Active methods analysis is visualized in figure 15.

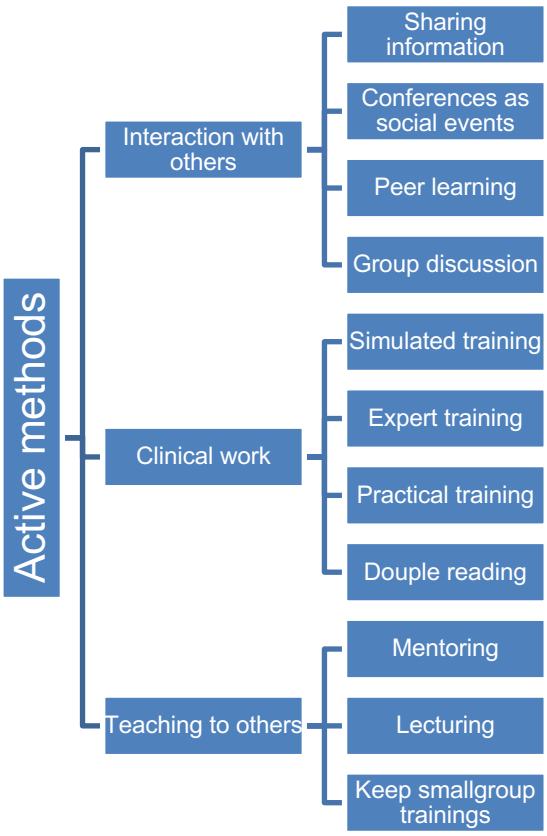

Figure 15. Active methods-theme, groups and sub-groups visualized.

Interactions with others was one major method of enhancing learning. Double-reading of breast mammography images, multi-professional case meetings and colleague dialogue are common for radiologists and are informative way to improve continuous education

and prevent fixing to old habits. Information sharing and discussion about the clinical cases was seen as one of the most efficient method of gaining understanding on new imaging modalities. These were stated to happen in workshops, courses and in clinical practice.

> Kyllähän se vertaisoppiminen ja kysyminen toiselta oli hyvin tärkeitä siinä kohtaa varsinkin, kun sitä työtä tehdään. (Interview 2)
>
> Peer learning and asking from other was very important, especially while working. (Translation by researcher)
>
> Siinä kaikki oli pikkasen huuli pyöreänä kuitenkin alussa. Että mitä tässä ja miten tämä asia näkyy nyt tällä menetelmällä, kun se on aikaisemmin tällä menetelmä näkynyt tuolla tavalla. Et “katos vaan - tämä näyttääkin tosi paljon selvemmin tuon” ja näin pois päin. Tuli tätä kokemusten vaihtoa ja tämmöistä yhdessä pohtimista, että mihin sitä kannattaa käyttää ja mihin se soveltuu hyvin. (Interview 3)
>
> Everyone was little astonished in the beginning. How to use and how this modality shows this when it’s previously seen that way with another modality. Like: ”See, this shows that more clearly” and so on. We had this experience exchange and pondering together, that where this should be used and where it implements well. (Translation by researcher)

All interviewees stated that sustainable understanding of new breast modality was achieved only by clinical work. This was seen to be a complex combination of several professional tasks, e.g. gaining experience on new modality with patient examinations and peer learning. It was seen beneficial to compare the novel modality to other imaging modalities and previous experiences in the field of breast disease.

> Jos pelkästään käyt luennolla, etkä koskaan tee tätä työtä niin eihän se niin kuin eläväksi muutu se tieto, mitä sieltä saa. (Interview 3)
>
> If you just attend to lectures and never really work, the information won’t translate to actual reality. (Translation by researcher)
>
> Kyllä se pitkälti tulee myöskin potilastyöskentelyn kautta, kun huomaa, minkä tyyppiset syövät ei oikeasti löydykään sillä tomolla ja minkä tyyppisiin siitä on apua. Se on ehkä sellainen pidempi prosessi. (Interview 4)
>
> It mainly comes via clinical work to understand what types of cancers are actually not found with tomosynthesis and to what types tomo is helpful. It is perhaps a longer process. (Translation by researcher)

When considering a completely new modality, expert trainings were seen beneficial. To have more experienced colleague or a trainer to share information from own experiences and guide the modality integration, it was believed to enhance implementation and accelerate learning. Experts with similar working culture and language were considered to be most efficient.

> Se että pysyy ajan hermolla ni vaatii sitä, että on hyvin verkostoitunut itseään älykkäämpien ihmisten kanssa, jotka pureskelee sen tiedon valmiiksi ja kertoo sen miten pitäisi tehdä. (Interview 4)
>
> To stay on the nerve requires that you are well connected to people who are smarter than you, who digest the information and inform how things should be done. (Translation by researcher)

Information from experienced pioneer users can aid and accelerate modality integration for new clinical users. Interviewees stated that one of the most important way of learning new modalities was discuss with colleagues and to together reflect the gained information to pre-existing experience of old imaging modalities.

> Silloin meillä kävi yks kliinikko sitä opettamassa…Tekee tiedettä ja työtä kyseisellä laitteella ja on tehnyt kehitystyötä. Hän opetti ja hän oli selvästi neutraali ja niin sen pitää olla. Toisaalta hänellekin tuli yllätyksiä sitten täällä meidän puolella, asioita, mitä hän ei ollut tiennyt ja toivoi, että heidän laitteelle saadaan niitä samoja toimintoja. Että se oli ihan molemmin puolin hyödyllistä. Parasta se onkin, et radiologi puhuu radiologille, koska sitten saadaan suoraa tekstiä. (Interview 4)
>
> We had clinician to teach us… He/she does research and works with the system and has made R&D-work. He/she taught us, and was clearly neutral, as should be. On the other hand, he/she was surprised here at our site with things he/she didn't know and hoped that they would get the same features to their device. It was mutually beneficial. (Translation by researcher)

> Me työskenneltiin yhdessä ja työnohessa vähän opeteltiin. Otettiin vain joltain potilaita tomot ja ylipäätänsä katsottiin, et miten niitä kannattaa katsoja ja sitten hän kertoi asioita, mitkä tomolla ei näy ja mitkä näkyy hyvin. (Interview 4)
>
> We worked together and learned a little while working. We did tomosynthesis to some patients and generally considered on how the images should be viewed and he/she told what features are not visible with tomosynthesis and what are visible. (Translation by researcher)

Active learning associated to the feel of competence will improve understanding of the subject. Reforming gained knowledge with practical exercises of clinical cases and sharing acquired knowledge to others will enhance sustainable learning. Teaching others was also seen beneficial by enhancing the overall understanding of known matter.

> Onhan se (muille opettaminen) antanut paljon. Kyllä siinä oppi itsekin. Ja kun tekee jotain luentoa, vaikka aika tutustakin aiheesta niin voi löytää jotain sellaista mitä ei ole tai jonka on oppinut jollainlailla kollegoilta, mutta ei ole koskaan lukenut paperilla. Ja saa siitä sen et, minkä takia tämä oli näin vielä kun perehtyy. (Interview 2)

> Learning to others has given a lot. You learn as well. When you do lectures – even from familiar subject- you can find something that you have not understood, or you have learned somehow from colleague, but you have never read on a paper. And you properly understand. (Translation by researcher)

8.3 Additional information gained

When considering the content and methods to be implemented to an online e-learning service for interpreting certain breast imaging modalities the results of this research give direction for the service design planning. There are few other topics that were acknowledged from the interview data and were considered to be important to disclose. Technical skills, user motivation and user competence are covered in next chapters.

8.3.1 Variation of users' technical skills

Adult students' variable with the level of technical skills. In the future this variation will be minor with next generations possessing more universal IT-skills. Theoretical background demonstrated that e-learning requires self-directing qualities from users to be successful. During interviews using online e-learning solutions were noted to be a part of future.

> Minä voin sanoa, että edustan vähän vanhempaa, eri sukupolvea. Että en käytä chattiä muutenkaan, mutta uskon että kyllä nuoremmat radiologit mielellään käyttäis, ehdottomasti. Se on varma tulevaisuus itseasiassa. (Interview 1)

> I can say that I represent different, older generation. I don't use chat at all. But I believe that younger radiologists would want to use, absolutely. It'll be a norm in the future as a matter of fact. (Translation by researcher)

As stated earlier in the results real patient cases play an important part when acquiring knowledge on new breast imaging modalities. Online learning portal should contain a data pool of anonymized patient cases to be downloaded by the user to a local hardware. This enables case interpretation from familiar diagnostic workstation and user doesn't need to consume resources such as time and effort on learning a non-relevant viewing software.

> Että täytyy ottaa huomioon se, että minkä ikäinen tai kuinka paljon tietotekniikan kanssa muuten on tekemisissä, et miten sitten kauan menee siihen että oppii katsomaan tietynlaisella pacsilla. Esimerkiksi pacs-järjestelmätkii on erilaisia: eri nappulat toimii eri tavalla. (Interview 2)
>
> It needs to be taken account - how old or how much associates with IT- on how long it takes to learn to view images with certain PACS-system. E.g. PACS-systems are different, buttons work differently. (Translation by researcher)

8.3.2 Motivation to use e-learning solution

Regarding to motivation radiologists who this interactive e-learning portal is meant for should have or create inner motivation for learning new breast modalities via e-learning. Amotivation towards IT can be an issue for e-learning. Three radiologists mentioned dislike for additional computer use after working hours. This can affect the motivation to use e-learning solutions and lower the resources users are willing to spend with training. Thus, lowering the change for sustainable learning via e-learning.

> Kaikki verkkoportaalit ja kaikki minulla on aversio niihin, mutta nuoret tykkäävät. Minä inhoan kaikkea, mitä pitäisi jatkaa tässä (tietokone)työympäristössä, koska se on hirveän rasittavaa silmille. (Interview 4)
>
> All online portals and that sort of things – I have an aversion to them. But young like them. I hate everything that needs to be continued in this (computer) surrounding because it's awfully straining for eyes. (Translation by researcher)

> Koulutuksissa on myös se sosiaalinen ympäristö, että pääsee näkemään ne vapaa-ajat niitä muita ihmisiä. Et kyllä tässä kun tekee seulontatyöta vielä yksinään päivät pitkät, et tässä avaisi vielä tietokoneen oppimiseen yksinään. No, silloin ainakin vähenee se aika mitä siihen jaksaa keskittyä. (Interview 2)
>
> In conferences you have the social environment, you get to see other people on your free time. When you do screening alone all day long, to think

> that you'd open the computer again for learning alone…. mmm, at least the time to concentrate is reduced. (Translation by researcher)

For those who are lacking inner motivation for the task, extrinsic motivation will be the driving force and therefore it will be important to create the content as interesting and inspirational to enable sustainable learning and positive experience. To furthermore promote this the service should be clear and easy to use so that only few resources are spent on learning the use.

8.3.3 Considering users level of competence

Interviewees saw it beneficial if training would have different levels according to user experience. The patient case content and practical testing could vary from basics to more specialised and challenging ones.

> …riippuu radiologin tasosta, että esimerkiksi minä en enää käy perus workshopissa, koska ne ovat perustietoa, mutta residentit ja aloittelevat aloittavat alusta... Niitä kursseja voisi olla lääkärin tason mukaan, tai kokemuksen mukaan (Interview 1)

> …It depends of the level of the radiologist, e.g. I don't attend to basic workshops, because they are too basics. But residents and beginners start from the beginning. Courses could be according to doctor experience level. (Translation by researcher)

Several levels of content would serve solution users with different experiences. Users with limited experience could start from basics of the modality. They would not get too challenging tasks or information, which could affect their motivation and have negative impact to their learning flow. Experienced radiologists would not need to spend resources to known matters and basic clinical cases. They could concentrate to challenging tasks and special cases to improving learning flow and the feel of competence.

9 Discussion

According to results learning new breast imaging modalities requires social interactions. This means that e-learning solution should be used as a supportive service mixed with other teaching methods to enable social interactions. For training breast imaging modalities e-learning solution alone is unable to offer complete learning for the topic. Blended

learning with passive learning methods offering content for modality introduction and clinical content in e-learning solution combined with active learning methods in workshop or practical clinical training on-site would be suitable combination for training breast modalities. Used as a part of blended learning, the e-learning solution is able to fulfil desired competency and learning outcomes to provide overview of selected breast imaging method, aid the implementation of the method to clinical workflow and help image interpretation.

Results show that passive learning methods are suitable to be used in e-learning solution. In passive learning information and content can be offered to student without any interactions to others e.g. teacher or other students. As stated earlier online e-learning is an active self-directed learning process (Vahtivuori-Hänninen 2004 p11). The information is offered to participant to internalize and process it independently without feedback from information offeror. This traditional teaching method has benefit of being able to provide wide material and basic principles of topics to large pools of participants in a relatively low resource and fast way.

Content that is possible to offer via passive learning should contain the information in various forms to support different types of learners. With gaining the same information from different sources and forms we can ensure a well-structured and efficient semantic network for the participant (Järvilehto 2014). This will ensure sustainable deeper learning for various learners.

Autonomy, competence and relatedness are our main psychological needs that can enhance our inner motivation and activate personal commitment (Niemiec - Ryan - Deci 2009). The e-learning service should aim support these three psychological needs that are seen as key factors of sustainable learning. Results suggest that passive learning methods should be implemented to e-learning solution. The passive learning methods would promote participant autonomy with enabling self-directed learning. Participants can independently select the content to concentrate on. The feel of autonomy is well supported in interactive e-learning solution, because the use isn't attached to a certain location or time. With the feel of autonomy participants are more commitment to learning, their level of gaining new information is higher and they feel better.

Radiologists stated in interviews that learning new breast imaging modalities is a long process that evolves along with clinical work. Clinical work enhances competence, one

of our psychological need. Competence is increased when we get challenging and interesting tasks done, we reach goals and are able produce valuable results. Viewing clinical cases and making diagnosis according to information seen in new imaging modality evolves users' knowledge and increases the sense of competence. Feel of competence could be implemented to online e-learning solution with e.g. interactive self-testing module.

As earlier stated in research results interaction with other was seen important when gaining knowledge on breast modalities. The need to be connected to others is the third psychological need, relatedness. Meaningful connections and the feel of being part of a group is enhanced in small-group trainings. Interviewees stated that they prefer face-to-face meetings with colleagues and appreciate the social events connected to conferences. The feeling of belonging and relatedness could be built to the interactive e-learning portal with possibility for radiologists to do double-reading with clinical exercise cases with other participants. Discussion forums or chat solutions could be added to the e-learning solution to enable participant communication and commitment.

Rigby and Ryan study show that people playing e-learning games can advance better in tasks with collaboration compared to participants acting alone (Rigby - Ryan, 2011). If participants are able collaborate in an interactive e-learning solution, we can support all three psychological needs: autonomy, competence and relatedness. E-learning solution could have service to share own self-test results with others, possibility to discuss the clinical cases and even teach others. Like stated earlier information sharing is an efficient learning tool.

E-learning can face some challenges with negative attitude from system stakeholders. Users need to possess certain competence in IT-skills to be able to use and benefit from e-learning solution which was noticed in the results. Lack of these IT-skills can lower motivation to use e-learning and prevent sustainable learning. During interviews participants acknowledged that e-learning is going to be standard in the future. Three of the interviewees stated that they dislike any additional computer use after working hours. During e-learning solutions' product development this needs to be considered. E-learning solution should be interesting and attractive to ensure radiologists participation. From e-learning service provider point of view result verified that the implemented content should be done with high quality to maintain user interest and ensure sustainable learning. This requires continuous improvement actions and resources from service provider.

Language requirements and software design should be taken account in e-learning planning phase, if the e-learning service is going to be internationally available. As the most benefit of e-learning service is seen in areas of low-resources - it should be considered if language options should be applied to the portal. It could be challenging if not impossible to provide all learning material in several languages, but it would be beneficial to translate portal navigation and invest in user friendly service design. The used wording in the portal should be clear and easy. Järvilehto states that no matter how complex the subjects or content is, the simplest wording should be used, because long sentences with complex words are seen as difficult and non-intellectual (Järvilehto 2014). Keeping the solution simple and easy to use will also prevent unnecessary time consuming to software usage and lower aversion towards e-learning.

9.1 Research reliability

Reliability of this study was evaluated according Tuomi and Sarajärvi (Tuomi – Sarajärvi 2018). Aspects of research reliability are covered in the following chapters.

9.1.1 Meaning of research and researcher commitment

Main purpose of the research was to gather information from experienced breast radiologists about their previous experiences on learning and training new breast imaging modalities. Results formed the understanding on what kind of learning methods and content should be implemented to interactive e-learning solution for image interpretation on mammography, tomosynthesis and synthetic 2D-images.

This was an interesting process for the researcher to gather information about the topic and talk to experts. Gained information did include some surprising aspects that were not expected beforehand and this did enhance the interest and commitment to research. Research results can be used as a background information to guide future product development of an interactive e-learning solution and thus directly affect researcher’s future work tasks. This straight connection to between the study and researcher’s employment increased researcher’s commitment to the study.

9.1.2 Interview participants

Research sampling is described in more detailed in chapter 7.1 Sampling. During participant recruitment there was seen non-response bias of the sampling. Email was used as the selected method of contacting possible participants. Only few responses were received from willing interviewees. Non-response error is seen when individuals from sampling frame can't be contacted or they refuse to collaborate or are unable to provide needed data (Bryman 2008 p169). During participation recruitment interview invitations were sent once with a second email to remind about the possibility to participate for those who did not answer to the initial email. Excess reminding emails were considered to seem forcing to participate and annoy the possible participants, also possibly affect motivation to attend and share information during interview; thus, affecting the analysis of the data and results.

Participants were selected by purposive (non-probability) sampling and snowball sampling. Snowball sampling possess a risk of sampling bias as interviewees could recommend others with similar mind set as themselves. Human judgement could affect the selection, thus some persons from the suited population would be more likely to be recommended and selected compared to others (Bryman 2008 p169). To prevent this bias two sampling methods were used. The first participants with known different key characteristics were contacted with purposive sampling directly. This was done to ensure that the distortion of interviewee representativeness was kept to minimal. Risk of snowball sampling bias is seen minor in qualitative research strategy than in quantitative because external validity and need for generalization are less critical in qualitative research (Bryman 2008 p185, 415).

All participants were well suited to the expert interviewee part. They had strong experience and were eager to share their knowledge during the interviews. Pre-existing connection between some of the participants and the interviewer was not seen to create bias. Connection was considered to improve rapport building.

9.1.3 Data collection reliability

Data collection is described in more detailed in chapter 7.2 Data collection. The interview planning could have been planned more though out by the researcher. This was mainly because of lack of interview data collection experience of the researcher and because

of the eagerness of starting the interviews as soon as possible. The interviews were thematic, allowing free discussion within the pre-planned topics and because of this the loss of strict planning was not seen as an issue or creating bias to data. The first interviews were an exciting situation for the interviewer. Confidence with the interview situation was gained with every interview done.

Probing to get more information from the participants during the interviews was minor during first meetings. This was because of the fear of affecting the answers and creating bias to the data. Probing was seen challenging by the researcher in the beginning which was mainly because of researchers limited interview experience. Probing is more commonly problematic when doing structured interviews and the interviewer needs to make an intervention to aid respondent to give more information. This may influence interviewee and their responses and thus cause an error to data (Bryman 2008 p206). This research interviews were thematic with open ended main questions to guide the discussion. Thus, probing was not considered causing bias to gathered data.

Four interviews were made face to face and one via phone conference. All interviews were recorded with mobile application to make sure all information was accessible and unchanged. Recorded interviews were transcript to text form for content analysis. Information gained from the interviews was exciting, especially the unpredictable notices that came as a surprise to the researcher. Some of these exciting information pieces did not have anything to do with the research questions and needed to be left out of the thesis. This felt challenging, took time to be understood and accepted by the researcher.

Sample size of this study was relatively small with five interviews. Data from the interviews started deliver similar results. This was considered to be a proof of theoretical data saturation meaning that gained data was enough for this thesis study. Information gained from additional interviews might have risen individual remarks on the topic. Main theoretical themes achieved with this data was seen to be enough for the thesis.

9.1.4 Research analysis and reporting

Research analysis and research results are described in more detailed in chapter 7.3: Analysis methods and in chapter 8: Results. As a new researcher with limited experience on qualitative research methods there were several stages during this research that caused challenges. These were often common pitfalls that were warned beforehand and

had been made obvious by literature. From the beginning researcher needed to be reminded several times not to make the research to wide and the topic needed to be narrowed to be able to be done with present staff and time resources.

Research data analysis was the most time consuming mainly due the researchers' lack of experience. Interview data contained many interesting details and notices that did not have anything to do with the research questions and needed to be left out. This was first seen as loss of interesting information that should be brought to everyone's attention. After reading more about qualitative analysis methods and implementing new knowledge to analysis is was obvious that some details from the interviews needed to be left to other studies and were not essential information to this research.

9.1.5 Research ethics

This research was made by following responsible conduct of research. According to Tuomi and Sarajärvi violation of responsible conduct of research can be e.g. insufficient referring to previous researches, misleading reporting of methods and results and false resulting (Tuomi – Sarajärvi 2018 p 150-151). In qualitative research ethics are often related to research activities such as data gathering, participant information and reliability of analysis method. Participation anonymity and result presentation can cause ethical issues (Tuomi – Sarajärvi 2018 p 152-153). In this chapter ethical issues are considered and needed actions that were implemented explained.

Methods and results of this research are reported honestly and with detailed information. Transparency and information sharing were maintained with interview participants by offering information about the research and researchers own background, pro-actively asking permission and making sure if the participants had any related questions. All interview participants were made aware of and reminded several times on interview voluntary and the possibilities to cancel their participation at any stage of the research. This was informed in the initial recruitment email. It was written in the interview information letter. Voluntary participation and acknowledged possibility to cancel participation was also asked and signed by all interviewees in informed consent forms and it was spoken and recorded in the beginning of the interviews.

With limited sample size of five interviewees the anonymity can be challenging to maintain. Because of this exact geological location of participants is not to be told. All citations

used in reporting the result were removed from any additional information that might compromise that anonymity of the interviewee. Citations are transcript to basic spoken language and all traces of possible dialects have been removed. Citations only include the result related content and participants cannot be recognized from them. All participants gave positive opt in in written informed consent form that citations can be used to demonstrate results as long as participant anonymity is not compromised. According to General Data Protection Regulation (GDPR) that came to effect on 25th of May 2018 consents need to have opinion to inform 'agree' or 'not agree' thus pre-ticked boxes or overall agreements are not allowed (GDPR-info 2018).

According to the GDPR all interviews were noted that they have right to be forgotten if they inform to cancel their participation. This means that their interviews and all related data (audio records and written transcripts) will be deleted immediately. Immediately was defined in the informed consent form to be within one month from the participation cancellation date. All interview data will be deleted at the end of year 2019. All interview and research data containing personal information of the participants is stored to a locked or password secured location accessed only by the researcher.

10 Conclusion

In this study e-learning was found to be suitable solution for providing modality introduction and help teaching new breast imaging modalities. According to results the e-learning solution should contain passive and active learning methods and content for modality introduction as well as clinical content to promote learning. Social interactions, practical training and clinical work are required to gain complete understanding of the new breast imaging modality. Because of this e-learning should be used as a part of blended learning with other teaching methods that enable social interactions in clinical setting.

This subject seems to include many possibilities for further research. Similar study covering international participants would bring more insight to the matter and could evolve ideas on the content and material to better serve international clients. All interviewees were experienced breast radiologists, as stated earlier; radiologists with less experience might possess different needs for content and used methods. It would be interesting to examine the opinions of radiologists with less experience about the matter. For this research the main interest was to interview experienced breast radiologists with experience on tomosynthesis. This was to make sure interviewees were recently trained to use a

novel breast imaging modality that was important to the research questions. Additional research with wider sampling frame would bring more information on the topic.

After initial launch of the e-learning solution, a study with focus group interview of the users should be done to find out participants opinions about the service. Collecting feedback on possible improvement needs would be important for continuous improvement and system maintaining. With this action research could be done to produce and implement continuous improvement cycle for the interactive e-learning solution, e.g. Plan-Do-Check-Act cycle, to improve the e-learning solution further on and collect feedback from the users.

References

Aparicio, Manuela – Bacao, Fernando – Oliveira, Tiago 2015. An e-Learning Theoretical Framework. Article: Educational Technology & Society. 02/2015, volume 19, issue 1, pp 292–307. Available: https://www.j-ets.net/ets/journals/19_1/24.pdf Accessed: 31.12.2018

Aparicio, Manuela – Bacao, Fernando – Oliveira, Tiago 2014. Trends in the e-Learning Ecosystem: A Bibliometric Study. 20th Americas Conference on Information Systems, AMCIS 2014. Available: https://www.researchgate.net/publication/267441431_Trends_in_the_e-Learning_Ecosystem_A_Bibliometric_Study Accessed 2.1.2019

Barkhausen, Joerg – Rody, Achim – Schaefer, Fritz 2016. Digital breast tomosynthesis – Technique and Cases. Thieme Publisher. Stuttgart.

Bryman, Alan 2008. Social Research methods. Third edition. Oxford University Press. New York.

Coleman - M. P. - Quaresma, M. – Berrino, F. – Lutz, J. M. - De Angelis, R. - Capocaccia, R. - Micheli, A. 2008. Cancer survival in five continents: a worldwide population-based study (CONCORD). The lancet oncology: 08/2008, volume 9, issue 8, pp 730-756. Available: https://www.sciencedirect.com/science/article/pii/S1470204508701797. Accessed 2.1.2019

Curran, Vernon – Noseworthy, Tanya 1999. Distance Learning and the Health Professions A Synthesis Report of the Literature Investigating Continuing Professional Health Education at a Distance. Newfoundland: Memorial Univ. St. John's, Centre for Collaborative Health Professional Education. Available: https://eric.ed.gov/?id=ED461740

DeSantis, C. E. - Ma, J. - Goding Sauer, A. - Newman, L. A. - Jemal, A. 2017. Breast cancer statistics, 2017, racial disparity in mortality by state. A cancer journal for clinicians, 10/2017: Volume 67, issue 6, pp 439-448. Available: https://onlinelibrary.wiley.com/doi/abs/10.3322/caac.21412 Accessed 2.1.2019

Doulík, Pavel - Skoda, Jiri - Šimonová, Ivana 2017. Learning Styles in the e-Learning Environment: The Approaches and Research on Longitudinal Changes. International Journal of Distance Education Technologies. 15. 45-61. Available: https://www.researchgate.net/publication/313472672_Learning_Styles_in_the_e-Learning_Environment_The_Approaches_and_Research_on_Longitudinal_Changes Accessed 20.3.2019

EBreast 2018. Webpage http://www.earlydetectionofbreastcancer.com Visited 3.1.2019

ECR 2019. European Congress of Radiology: Web page https://www.myesr.org/past-congresses/ecr-2019 Accessed 3.6.2019

Eusobi 2019. European Society of Breast Imaging: Web page https://www.eusobi.org/congress/ Accessed 3.6.2019

Ferlay, J. – Ervik, M. – Lam, F. – Colombet, M. – Mery, L – Piñeros, M. – Znaor, A. – Soerjomataram, I. Bray, F. 2018. Global Cancer Observatory: Cancer Today. Lyon, France: International Agency for Research on Cancer. Available from: https://gco.iarc.fr/today Accessed 2.1.2019.

Ferreira R. 2019: Example images. Images courtesy of Dr Ferreira, Santiago de Chile, Chile.

GDPR-info 2018. Webpage https://gdpr-info.eu/ updated 05/2018. Visited 10.5.2019

Gureckis, Todd M. – Markant, Douglas B. 2012. Self-Directed Learning: A Cognitive and Computational Perspective. New York University. Article: Perspectives on Psychological Science: 09/2012, volume 7, issue 5, pp 464-481

Harju, Aune – Risikko Paula 2003. Sosiaali- ja terveydenhuollon henkilöstön täydennyskoulutuksen nykytila ja parhaat käytännöt – Loppuraportti 14.1.2003. Ministry of Social Affairs and Health, working group memorandum 2002:23.

Hologic 2019. Hologic-Education: Web page: https://hologiced.com/ Accessed 3.6.2019

Hologic 2017. Hologic EQUIP Training: Enhancing Quality Using the Inspection Program. Web brochure. Available: https://www.hologic.com/sites/default/files/2017/Products/Breast%20%26%20Skeletal%20Health/Service/SS-00640_Equip%20Training%20sellsheet_FINAL.pdf Accessed 3.6.2019

Hrastinski, Stefan 2008. Asynchronous and Synchronous E-Learning: A study of asynchronous and synchronous e-learning methods discovered that each supports different purposes. EDUCAUSE Quarterly: 2008, volume 31, issue 4, pp 10–12

ITU 2018. Achieving universal and affordable Internet in the least developed countries, Thematic report. Available: http://unohrlls.org/custom-content/uploads/2018/01/D-LDC-ICTLDC-2018-PDF-E.pdf Accessed: 27.12.2018

Järvilehto, Lauri 2014. Hauskan oppimisen vallankumous. PS-kustannus, Jyväskylä

Karellas, Andrew – Vedantham, Srinivasan 2013. Detectors for digital mammography. In Gary J. Whitman and Tamara Miner Haygood (Eds.). Digital Mammography: A Practical Approach. Cambridge: Cambridge University Press, pp 1-16.

Kimpimäki, Minna – Laitinen, Pirjo - Lohineva-Kerkelä, Mirva 2008. Verkko opiskeluympäristönä- Oikeustieteen opettaminen. Ed. Poikela Esa, Poikela Sari. Laatua opiskeluun – Oppiminen ja opetus yliopistossa. Tampere: Juvenes print. 144-160.

Law on Healthcare Personnel 1994/559 §18. In Naantali 28.6.1994

Leinonen, Jaana 2008. “Keskustelut olivat parhainta antia” – Vuorovaikuttaminen verkkokurssilla. Ed. Poikela Esa, Poikela Sari. Laatua opiskeluun – Oppiminen ja opetus yliopistossa. Tampere: Juvenes print. 161-174.

Liu, Q. – Peng, W – Zhang, F. - al. 2016. The effectiveness of blended learning in health professions: Systematic review and meta-analysis. Journal of medical Internet research 2016, volume 18, issue 1. Published online 4.1.2016

Manninen, Jyri 2003. Ohjaus verkkopohjaisessa oppimisympäristössä. In Matikainen J. Ed. Oppimisen ohjaus verkossa. Helsinki: Yliopistopaino.

Masie Elliot 2006: The blended learning imperative. In Bonk Curtis J., Graham Charles R. Ed.The Handbook of Blended Learning: Global Perspectives, Local Designs. San Francisco: Pfeiffer

Mayes, Jonathan – White, Andrew 2016. How Smartphone Technology Is Changing Healthcare in Developing Countries. Web article 1.11.2016 https://www.ghjournal.org/how-smartphone-technology-is-changing-healthcare-in-developing-countries/ Accessed 27.12.2018

Metsälä, E. - Richli Meystre, N. - Pires Jorge, J. - et al. 2017. European radiographers' challenges from mammography education and clinical practice – an integrative review. Insights Imaging. Available: doi:10.1007/s13244-016-0542-1

Morri, Aldo 1997. A Bright future for distance learning: One touch/hughes alliance promotes interactive "e-learning" service. Web article 17.10.1997, Connected Planet Online. Available: http://archive.li/KAvr2 accessed 31.12.2018

Nees, Alexis 2013. Digital breast tomosynthesis. In Gary J. Whitman and Tamara Miner Haygood (Eds.). Digital Mammography: A Practical Approach. Cambridge: Cambridge University Press. pp 109-124.

Niemiec, Christopher - Ryan, Richard - Deci, Edward 2008. The path taken: Consequences of attaining intrinsic and extrinsic aspirations in post-college life. Web article available: https://selfdeterminationtheory.org/SDT/documents/2009_NiemiecRyanDeci_JRP.pdf Accessed 20.12.2018

Noesgaard, S.S. - Ørngreen, Rikke 2015. The effectiveness of e-learning: An explorative and integrative review of the definitions, methodologies and factors that promote e-Learning effectiveness. Article: Electronic Journal of e-Learning. 2015, volume 13, issue 4. pp 278-290. Available: https://files.eric.ed.gov/fulltext/EJ1062121.pdf Accessed 20.3.2019

Planmed 2018. Planmed Clarity™ 3D Digital Breast Tomosynthesis brochure. Product marketing brochure.

Pratikakis, Ioannis – Karahaliou, Anna – Vassiou, Katerina – Virvilis, Vassilis – Kosmopoulos, Dimitrios – Perantonis, Stavros 2007. eMedI:Web-Based E-Training for Multimodal Breast Imaging. Article: World Academy of Science, Engineering and Technology International Journal of Medical and Health Sciences: 2007, volume 1, issue 7, pp 188 -194

Rafferty, E.A. – Park, J.M. – Philpotts, L.E. – Poplack, S.P. – Sumkin, J.H. – Halpern, E.F. – Niklason, L.T. 2014. Diagnostic accuracy and recall rates for digital mammography and digital mammography combined with one-view and two-view tomosynthesis: results of an enriched reader study. American Journal of Roentgenology. 02/2014, volume 202, issue 2, pp 273-81. Available: http://www.ncbi.nlm.nih.gov/pubmed/24450665

Rafferty, E.A. – Niklason, L. - Jameson-Meehan, L. 2006. Breast tomosynthesis: one view or two? Presented at the Radiological Society of North America annual meeting; Chicago, Illinois. 2006.

Ratanaprasatporn, Linda - Chikarmane, Sona A. – Giess, Catherine S. 2017. Strengths and Weaknesses of Synthetic Mammography in Screening. Web article. Published: 13.10.2017. Available: https://doi.org/10.1148/rg.2017170032 Accessed 4.6.2019

RSNA 2018. The Radiological Society of North America. Web page: https://www.rsna.org/ Accessed 3.6.2019

Ryan, Richard M. – Rigby, C. Scott – Przybylski, Andrew 2006 The Motivational Pull of Video Games: A Self-Determination Theory Approach: Article, Motivation and Emotion 12/ 2006, Volume 30, Issue 4, pp 344–360 Available: https://selfdeterminationtheory.org/SDT/documents/2006_RyanRigbyPrzybylski_MandE.pdf Accessed 20.12.2018

Ryan, Richard M. – Deci, Edward L. 2000a. Intrinsic and extrinsic motivations: Classic Definitions and new directions. Article. Contemporary Educational Psychology. 01/2000, volume 25, issue 1, pp 54-67. Available on: https://ac.els-cdn.com/S0361476X99910202/1-s2.0-S0361476X99910202-main.pdf?_tid=5ed4baf4-b860-403f-a0db-717d0e7d1942&acdnat=1545306208_7ec60853e6ae0be9eaed5bcf82f51bb6
Accessed: 19.12.2018

Ryan, Richard M. – Deci, Edward L. 2000b. Self-determination Theory and the Facilitation of instrinsic motivation, social development, and well-being. Article. American Psychologist. 01/2000, volume 55, issue 1. pp 68-78. Available on: https://selfdeterminationtheory.org/SDT/documents/2000_RyanDeci_SDT.pdf accessed: 19.12.2018

Ruiz, Jorge - Mintzer, Michael - Leipzig, Rosanne M. 2006: The Impact of E-Learning in Medical Education. Article: Academic Medicine. 3/2006, volume 81, issue 3, pp 207-212.

Salminen, Leena – Suhonen, Riitta 2008. Oppiminen ja oppimismenetelmät ja niiden hyödyntäminen ammatillisen kehittymisen tukena - Raportti täydennyskoulutuksesta ja sen mahdollisuuksista. Hämeenlinna: Hämeen Ammattikorkeakoulu

Skaane, P. – Bandos, A.I. – Eben, E.B. – Jebsen, I.N. – Krager, M. – Haakenaasen, U. – Ekseth, U. – Izadi, M. – Hofvind, S. – Gullien, R. 2014. Two-view digital breast tomosynthesis screening with synthetically reconstructed projection images: comparison with digital breast tomosynthesis with full-field digital mammographic images. Article: Radiology: 2014 volume 271, issue 3, pp 655–663

Tuomi, Jouni – Sarajärvi, Anneli 2018. Laadullinen tutkimus ja sisällönanalyysi. Tammi. Helsinki.

UN 2015. United Nations, Transforming our world: the 2030 Agenda for Sustainable Development, Available: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E accessed 27.12.2018

Vainionpää, Jorma 2006. Erilaiset oppijat ja oppimateriaalit verkko-opiskelussa. Doctoral thesis, University of Tampere. Tampere: Juvenes Print.

WCRF World Cancer Research Fund / American Institute for Cancer Research 2017. Diet, Nutrition, Physical Activity and Cancer: a Global Perspective. Continuous Update Project Expert Report 2018. Available at https://www.wcrf.org/sites/default/files/Breast-cancer-report.pdf accessed 2.1.2019

White, M.A. 1983. Synthesis of Research on Electronic Learning. Educational Leadership: 1983, volume 40, issue 8, pp 13-15. Retrieved December 31, 2018 from https://www.learntechlib.org/p/134860/.

Zuley, Margarita – Guo, Ben – Catullo, Victor – Chough, Denise - Kelly, Amy – Lu, Amy – Rathfon, Grace – Lee Spangler, Marion – Sumkin, Jules – Wallace, Luisa – Bandos, Andriy 2014. Comparison of Two-dimensional Synthesized Mammograms versus Original Digital Mammograms Alone and in Combination with Tomosynthesis Images. Radiology 2014, volume 271, issue 3, pp 664-671

Appendix 1: Interview letter 1

Saatekirje haastateltavalle

Maisteriohjelma Metropolia AMK, Health Business Management
Saara Muhli

Harjoittelumateriaali ja -menetelmät interaktiiviseen verkko-oppimisympäristöön mammografia-, tomosynteesi- ja synteettisien 2D- kuvien luentaan.

Teen maisteriopintojeni lopputyötä Helsingin ammattikorkeakoulussa Metropoliassa. Laadullisella tutkimuksella pyrin selvittämään rintaradiologien mielipiteitä ja ajatuksia interaktiivisen verkko-oppimisympäristön mahdollisesta sisällöstä ja käytetyistä harjoittelumenetelmistä. Tavoitteena on luoda pohjatietoa harjoittelutarpeista ja -toiveista sekä käytettävistä menetelmistä, joiden avulla verkko-oppimisympäristöä voitaisiin lähteä rakentamaan.

Pyydän Teitä osallistumaan teemahaastatteluun, koska Teillä on kokemusta ja tietämystä aiheesta tai teitä on suositeltu minulle. Osallistuminen tähän tutkimukseen on täysin vapaaehtoista ja osallistumisen voi halutessaan perua missä tahansa tutkimuksen vaiheessa. Haastattelun tiedot tullaan käsittelemään luottamuksellisesti, sekä tutkimuksen tuloksista poistettaan kaikki mahdolliset henkilötiedot ja muut tiedot, joista vastaaja voitaisiin tunnistaa. Henkilöllisyytenne ei tule muiden kuin minun tietooni.

Halutessanne osallistua tutkimukseen, ottakaa minuun yhteyttä haastatteluajan varaamiseksi. Haastattelu kestää noin 45 minuuttia, jonka aikana tutkimusaineiston keruu tapahtuu. Haastattelu voidaan toteuttaa myös puhelimitse. Haastatteluajan ja -paikan voitte päättää itse ja sopia siitä kanssani. Haastattelut on tarkoitus järjestää tammikuussa 2019. Haastattelut nauhoitetaan ja kirjoitetaan kirjalliseen muotoon, jotta tietojen analysointi helpottuu. Haastatteluversiot säilytetään vuoden 2019 loppuun turvattuna salasanalla ja tuhotaan edellä mainitun ajan jälkeen. Haastattelun alussa tallennetaan sanallisesti osallistujan suostumus tutkimukseen.

Teemahaastattelun runko

- **Haastattelun aloitus ja haastateltavan taustatiedot, lupa haastattelulle.**
- **Miten olet aikaisemmin tutustunut uusiin rintakuvantamismenetelmiin ja niiden kanssa työskentelyyn?**
- **Mitkä menetelmät koet toimivan parhaiten kuvanluennan harjoitteluun?**
- **Millaista sisältöä pidät tärkeänä uusien rintakuvantamismenetelmien tutustumiseen?**

Kiittäen,
Saara Muhli

Appendix 2: Interview letter 2

Saatekirje haastateltavalle

Maisteriohjelma Metropolia AMK, Health Business Management
Saara Muhli

Harjoittelumateriaali ja -menetelmät interaktiiviseen verkko-oppimisympäristöön mammografia-, tomosynteesi- ja synteettisien 2D- kuvien luentaan.

Teen maisteriopintojeni lopputyötä Helsingin ammattikorkeakoulussa Metropoliassa. Laadullisella tutkimuksella pyrin selvittämään, millaista sisältöä ja menetelmiä kokeneiden rintaradiologien aiempien koulutuskokemuksien pohjalta kannattaisi sisällyttää verkkoon rakennettavaan perustason oppimiskokonaisuuteen. Jotta kokonaisuus ei olisi liian laaja, aihe on rajattu tiettyihin kuvantamismenetelmiin.

Tarve verkossa tapahtuvalle perustasoiselle etäharjoittelulle ja tiedonsaannille on noussut esille eteenkin kehittyvien alueiden lääkäreiltä, joilla ei ole aikaisempaa kokemusta uusista rintakuvantamismenetelmistä.

Keskustelunomaisessa teemahaastattelussa haluaisin kuulla kokeneilta rintaradiologeilta, kuinka he ovat päässeet tutustumaan uusiin rintakuvantamismenetelmiin aiemmin, mikä niissä on koettu hyvänä ja miten niitä voisi kehittää?

Pyydän Teitä osallistumaan haastatteluun, koska Teillä on kokemusta ja tietämystä aiheesta tai Teitä on suositeltu minulle. Osallistuminen tähän tutkimukseen on täysin vapaaehtoista ja osallistumisen voi halutessaan perua missä tahansa tutkimuksen vaiheessa. Haastattelun tiedot tullaan käsittelemään luottamuksellisesti, sekä tutkimuksen tuloksista poistettaan kaikki mahdolliset henkilötiedot ja muut tiedot, joista vastaaja voitaisiin tunnistaa. Henkilöllisyytenne ei tule muiden kuin minun tietooni.

Halutessanne osallistua tutkimukseen, ottakaa minuun yhteyttä haastatteluajan varaamiseksi. Haastattelu kestää noin 45 minuuttia, jonka aikana tutkimusaineiston keruu tapahtuu. Haastattelu voidaan toteuttaa myös puhelimitse. Haastattelut on tarkoitus järjestää tammikuussa 2019. Haastattelut nauhoitetaan ja kirjoitetaan kirjalliseen muotoon, jotta tietojen analysointi helpottuu. Haastatteluversiot säilytetään vuoden 2019 loppuun turvattuna salasanalla ja tuhotaan edellä mainitun ajan jälkeen.
Haastattelun alussa tallennetaan sanallisesti osallistujan suostumus tutkimukseen.

Teemahaastattelun runko

- **Haastattelun aloitus ja haastateltavan taustatiedot, lupa haastattelulle.**
- **Miten olet aikaisemmin tutustunut uusiin rintakuvantamismenetelmiin ja niiden kanssa työskentelyyn?**
- **Mitkä menetelmät koet toimivan parhaiten kuvanluennan harjoitteluun?**
- **Millaista sisältöä pidät tärkeänä uusien rintakuvantamismenetelmien tutustumiseen?**