Mari Virtanen

THE DEVELOPMENT OF UBIQUITOUS 360° LEARNING ENVIRONMENT AND ITS EFFECTS ON STUDENTS’ SATISFACTION AND HISTOTECHNOLOGICAL KNOWLEDGE

UNIVERSITY OF OULU GRADUATE SCHOOL;
UNIVERSITY OF OULU,
FACULTY OF MEDICINE,
RESEARCH UNIT OF NURSING SCIENCE AND HEALTH MANAGEMENT
MARI VIRTANEN

THE DEVELOPMENT OF UBIQUITOUS 360° LEARNING ENVIRONMENT AND ITS EFFECTS ON STUDENTS’ SATISFACTION AND HISTOTECHNOLOGICAL KNOWLEDGE

Academic dissertation to be presented with the assent of the Doctoral Training Committee of Health and Biosciences of the University of Oulu for public defence in Auditorium P117 (Aapistie 5B), on 4 May 2018, at 12 noon

UNIVERSITY OF OULU, OULU 2018
Virtanen, Mari, The development of ubiquitous 360° learning environment and its effects on students’ satisfaction and histotechnological knowledge.
University of Oulu Graduate School; University of Oulu, Faculty of Medicine; Research Unit of Nursing Science and Health Management
Acta Univ. Oul. D 1455, 2018
University of Oulu, P.O. Box 8000, FI-90014 University of Oulu, Finland

Abstract

The digitalization of the society, the changing structures of education and the tightening resources have hastened the development of open learning environments. The aim of this study was to develop a ubiquitous 360° learning environment (360° ULE) on histotechnology (HT) education and evaluate its effects on student satisfaction and on HT knowledge in the biomedical laboratory science degree. In addition, the purpose was to provide systematic and transparent information on the development process. The study proceeded in two phases, i.e. development and evaluation.

In the development phase, the criteria for ubiquitous learning environments (ULE) and the use in higher education were defined by a scoping review. Based on the review the first version of ULE was produced in the histotechnology (HT) context. The ULE was piloted in a study where an experimental group (n = 29) studied via ULE and a control group (n = 28) via a conventional web-based learning environment (WLE). The data was collected at the end of the term by an electronic questionnaire, and it was analyzed statistically. In the evaluation phase, the effects on the student's HT knowledge of (n = 115) and on satisfaction (n = 112) were evaluated in a quasi-experimental study. The data was electronically collected in the beginning and at the end of the term and analyzed statistically.

The results from scoping review showed that the ULEs were not widely used in higher education. The criteria for ULEs were defined as flexibility, context-awareness, personalization and interactivity. These criteria were emphasized in the production of the ULE, evaluated in both phases. Based on the pilot study the flexibility, context-awareness and personalized operations were perceived as positive, whereas interactivity was seen as needing further development. In the final study, the students were very satisfied with the used ULE with significant improvements in their HT knowledge.

Based on the results the development process of 360° ULE was stated as effective and valid. The process was described systematically and transparently. Further development, optimization, and evaluation was recommended when implementing the 360° ULE as a part of HT curricula in the biomedical laboratory science degree.

Keywords: 360° technology, biomedical laboratory scientist, histotechnology, ubiquitous learning environment
Virtanen, Mari, Ubiikin 360° oppimisympäristön kehittäminen ja sen vaikutukset opiskelijoiden tyytystyvyiseen ja histoteknologian osaamiseen.

Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta; Hoitotieteiden ja terveyshallintotieteiden tutkimusyksikkö

Acta Univ. Oul. D 1455, 2018
Oulun yliopisto, PL 8000, 90014 Oulun yliopisto

Tiivistelmä

Yhteiskunnan digitalisoitumessa, koulutuksen rakenteiden muuttumassa ja resurssien tiukentumassa avointen oppimisympäristöjen kehittäminen korkeakoulupetuksen tarpeisiin on välttämätöntä. Tämän tutkimuksen tarkoituksena oli kehittää uusioppimisympäristö (ULE) histoteknologian opetuksen arvioimaan sen vaikutuksia bioanalytiikko-opiskelijoiden tyytystyvyyteen ja tietoon histoteknologista. Tavoitteena oli tuottaa uutta tietoa, jota voidaan hyödyntää kehitettäessä tulevaa oppimisympäristöä ja arvioitaessa 360°-teknikan laajempaa hyödyntämistä koulutuksen eri osa-alueilla.


Asiasanat: 360° technology, bioanalytiikko, histoteknologia, ubiikki oppimisympäristö
To You who love me most
Kiitokset


jokaista väitöskirjaa äärettömän paljon, koska tiedän sen vaatineen uskomattoman paljon.


Kovin luonteesta tämä tutkimus- ja kirjoitusprosessi on ollut. Huikeinta se, miten paljon olen oppinut! Monet näkevät väitöskirjatyön monen suuren päääkäisenä. Minä näen sen paljon vaihtavien suuren uuden ja merkittävän alkuna. Vaikea tarvitsen ollut hetkittäin raskas, se on kuitenkin ollut todella antoista!

Elämä. Rakkaampi. Ville, Sulo ja Vieno, Äiti ja Isä. Tämä on teille! Seuraavaksi tehdään jotain muuta!

Helsingissä 21.3.2018

Mari Virtanen
Acknowledgements

In some level, this research has started already years ago. The interest in research has been present throughout my whole career with a constant desire for lifelong learning. This doctoral study was a natural extension to gain the competence. The starting decision was easy; it was just waiting for the right time, place, and a relevant, engaging topic. And just as the saying goes, it found me when I least expecting it. This study smoothly integrated my strongest interests in histopathology, educational technology and technology-enhanced pedagogical development.

My deepest thanks go to my supervisors. Professor Maria Kääriäinen, who was enthusiastic about the research topic, even though it is still innovative and sometimes difficult to understand. Professor Elina Haavisto, who has been tirelessly, firmly and constructively criticizing and guiding me towards the outcome. I have stated many times that every Ph.D. candidate needs a supportive person, who embraces that role with 100% passion. That is you, Elina. My grateful thanks also to principal lecturer Eeva Liikanen with whom we have been able to develop the education of histotechnology from the view of the biomedical laboratory scientist student studying in a University of Applied Sciences. Thank you so much for your patient input. I value your work and your knowledge infinitely high. Thank you that you have been always able to see a bit further!

Thank you Docent Vesa Taatila and Docent Sini Eloranta for your intelligent comments as pre-supervisors. You have helped me to make my thesis even better. Now I have corrected even the smallest mistakes. Thanks to the members of the follow-up team, Helvi Kyngis, Satu Elo and Leena Rekola, for systematically following my progress. Our annual meetings have moved my process on as surely as any other signs of spring.

Thanks Päivi Helanto and Jukka for the annual meeting of the informal follow-up team on the rocks of Suomenlinna. With you, I became inspired by pedagogical development. Thank you for your warm friendship that has enabled the sharing of a wide range of ideas on the topic and around it. Without you, this research would just be pathological :).

Thanks for the whole team in Nursing Science and Health Care Research Unit in the University of Oulu. With you, this work has been easy. You all have played an important role in this process. Thank you Kristina for peer support. Your positive words and enthusiasm have been contagious. In addition, you are a nice traveling companion.

Thank you all who have showed with your own example that this process is even possible. I have got a lot of strength from You. After this process, I know I will appreciate every dissertation much more than you ever could imagine. Now I know that the process is incredibly demanding.
Thanks to my colleagues in Metropolia University of Applied Sciences who have supported me. There are so many of you. You have been genuinely interested in my work and delighted about my accomplishments. Thanks for enthusiastic persons in the digimenter network with whom I feel like at home. Thank you Elina Haavisto, the three Päivis Haho, Haapasalmi and Haarala, who have made my research possible in Metropolia UAS. Thank you Hannele for hiring me in the first place :).

Huge thanks to the financiers such as The Finnish Association of Histotechnology, The Finnish Nursing Education Foundation, The Laboratory Medicine Foundation LABES and The University of Oulu Scholarship Foundation. Without your financial support this research would not have been possible or at least it would not have been completed that fast.

Great thanks to all of you, who keep me connected to life and do something else than research with me. Thank you, mom and dad. Brothers and extended family. Friends. Kirsi O., Tanja H., Sirpa, Marjukka, Family Rousi. You are so important! And finally, how could I ever thank enough those who live with me. Thank you, dear family, for allowing full-time, uninterrupted and silent working time without stress about housework. For sharing joyful moments of success, with ‘cakes and goodies’, the grumpy comments and silence when facing great challenges. You have tolerated papers, folders, and unfinished plans laying all over the house. You have given time for endlessly long conversations and participated in rhetorical reflections. You have taken the kids to hobbies and taken care of daily routines. You have offered tireless walks in the sun and in the rain. In the midst of all confusion, you have enormously enjoyed that I got to work at home. You have loved me endlessly.

This research process has somehow felt very natural. The biggest achievements I have seen are in my increased competence. I have learned so much! Often a dissertation is seen as a great ending for something, but I see it much more as a significant beginning. Although the battle has been heavy at times, for the most parts it has been really rewarding!

My life. My dearest ones. Ville, Sulo and Vieno, Mother and Father. This is for You! Next, we will do something else!

In Helsinki 21.3.2018

Mari Virtanen
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>360°</td>
<td>360° spherical panorama image technique</td>
</tr>
<tr>
<td>360° ULE</td>
<td>ubiquitous 360° learning environment</td>
</tr>
<tr>
<td>AR</td>
<td>augmented reality</td>
</tr>
<tr>
<td>BLS</td>
<td>biomedical laboratory scientist</td>
</tr>
<tr>
<td>CLS</td>
<td>clinical laboratory scientist</td>
</tr>
<tr>
<td>CVI</td>
<td>content validity index</td>
</tr>
<tr>
<td>ECTS</td>
<td>European Credit Transfer and Accumulation</td>
</tr>
<tr>
<td>HT</td>
<td>histotechnology</td>
</tr>
<tr>
<td>LE</td>
<td>learning environment</td>
</tr>
<tr>
<td>LMS</td>
<td>learning management system</td>
</tr>
<tr>
<td>m-learning</td>
<td>mobile learning</td>
</tr>
<tr>
<td>MLS</td>
<td>medical laboratory scientist</td>
</tr>
<tr>
<td>MT</td>
<td>medical technologists</td>
</tr>
<tr>
<td>QR</td>
<td>quick response barcode</td>
</tr>
<tr>
<td>RFID</td>
<td>radio frequency identification</td>
</tr>
<tr>
<td>UAS</td>
<td>university of applied sciences</td>
</tr>
<tr>
<td>ULE</td>
<td>ubiquitous learning environment</td>
</tr>
<tr>
<td>u-learning</td>
<td>ubiquitous learning</td>
</tr>
<tr>
<td>WLE</td>
<td>web-based learning environment</td>
</tr>
</tbody>
</table>
List of figures and tables

LIST OF FIGURES

Figure 1. Model for educational evaluation
Figure 2. Framework of the study
Figure 3. The selection of eligible publications
Figure 4. 360° panorama image with digital objects
Figure 5. Functional objects in HT laboratory
Figure 6. The 360° ubiquitous learning environment
Figure 7. The web-based learning environment
Figure 8. Summary of the results

LIST OF TABLES

Table 1. The design of the study
Table 2. Component production and contributors
Table 3. Learning objectives
Table 4. Data collection instruments

LIST OF APPENDICES

Appendix 1. The instrument for assessing the level of students’ satisfaction
Appendix 2. The knowledge test for assessing histotechnology
Appendix 3. The self-evaluation instrument for histotechnological knowledge
List of Original Publications

In the Summary original publications are referred to in their numerals (I-IV):


Table of contents

Tiivistelmä
Abstract
Acknowledgements
Abbreviations
List of figures and tables
List of Original Publications
Table of contents

1 Introduction

2 Theoretical framework
   2.1 Medical laboratory science and histotechnology
   2.2 Ubiquitous learning environment
   2.3 Educational effectiveness
   2.4 Summary of the literature

3 Aim, research questions and hypotheses

4 Materials and methods
   4.1 Developmental phase
      4.1.1 The scoping review (Article I)
      4.1.2 The production of 360° ULE
      4.1.3 The implementation of 360° ULE (Article II)
   4.2 Evaluation phase
      4.2.1 Level of satisfaction (Article III)
      4.2.2 Changes in histotechnological knowledge (Article IV)

5 Results
   5.1 Developmental phase
      5.1.1 The criteria for ULE (Article I)
      5.1.2 The students’ perceptions on 360° ULE (Article II)
   5.2 Evaluation phase
      5.2.1 Level of satisfaction (Article III)
      5.2.2 Changes in histotechnological knowledge (Article IV)
   5.3 Summary of the results

6 Discussion
   6.1 Discussion of the main results
   6.2 Ethical considerations
   6.3 Validity and reliability
6.4 Contributions and practical implications ................................................. 62

7 Conclusions 65
  7.1 Recommendations ............................................................................. 65
  7.2 Future studies ................................................................................... 66
  7.3 Closing words .................................................................................. 66

References 69
Appendices 79
Original publications 87
1 Introduction

Digitalization of education is a globally relevant topic, which has been actively studied over the years. Digitalization enables a wide range of activities to transform conventional services with digital technologies, devices, resources and various sets of flexible, personalized and effective opportunities. (Jones & Jo 2004, Huang et al. 2011, Potkonjak et al. 2016). The ubiquitous learning have seen an extension of electronic and mobile learning (Shih et al. 2011) transcending the barriers between in-class and out-class activities with possibilities to study anytime and anywhere, and to participate beyond the limitations (Martin et al. 2013).

Multiple improvements have been reported when digital information has been used in education to enable universities to meet a broader range of student needs and mix in-class and online learning possibilities anywhere and anytime (European Centre for Parliamentary 2014). Prominent improvements have been recognized when learning environments, teaching methods and the pedagogy have been modernized by digitalization. The Finnish policy of higher education and science has promoted the open development of effective and efficient teaching methods and learning environments to raise the level of quality and competitiveness. (Ministry of Education and Culture 2017). Similar governmental agendas have been formulated in other European countries for example in Norway, Netherlands and Germany (Government of Norway 2016, Government of Netherlands 2016, The Federal Ministry of Education and Research of Germany 2017). These agendas and needs have encouraged the research and writing of this doctoral thesis.

Ubiquitous learning environments (ULE) are based on ubiquitous technology (Weiser 1991, Yahya et al. 2010, Shih et al. 2011). Ubiquitous learning can be seen as an expansion of electronic and mobile learning (Casey 2005) based on ubiquitous computing with high mobility and tight integration into the learning environment. The seamless communication between users, learning spaces, devices and embedded functional objects allows learning while moving, attaching learners to the current learning situation in the current place with highly accessible omnipresent digital resources and approaches for knowledge creation and communication (Cope & Kalantzis 2009, Liu & Hwang 2010, Yahya et al. 2010).

The composition of ULEs can vary. In general, ULEs combine authentic learning spaces, digital resources, technologies and devices as one learning environment. In particular, ULEs enhance flexible, personalized, interactive and context-aware learning and support the transition of theory in to practice (de Freitas & Neumann 2009).
ULE supports learning processes and seamless interactions. High accessibility, flexibility, permanence, personalization, and interactivity have been perceived as necessities (Weiser 1991, El-Bishouty et al. 2007, Huang et al. 2008, Ogata et al. 2008, Yahya et al. 2010, Huang et al. 2011, Chin & Chen 2013). The ubiquitous learning environments are not widely used or reported in health or medical science contexts.

The histotechnology and the histotechnological (HT) knowledge forms a part of the competence of biomedical laboratory scientist educated in biomedical laboratory science degree. HT knowledge forms the context of this study and is one of the main competences of biomedical laboratory scientists. HT knowledge is required in the histopathology laboratory where the scientists prepare the tissue samples for microscopical examination for diagnosis made by the pathologists, identifying tumors, autoimmune, inflammatory and degenerative diseases. HT centers on the detection of tissue abnormalities and the treatment of the diseases. (Karttunen & Pääkkö 2013, NSH 2017.) In this study, the HT knowledge is focused on HT processes as part of diagnosis and patient treatment, pathological basis of diseases, normal cell structure and tissue morphology, tissue sampling techniques and laboratory processes.

The teaching methods used through the ages have been strongly based on teacher’s strong competence, instructional lecturing (Davis 1998 in Taekman and Shelley 2010), teacher-centered in-class activities, self-directed learning activities and hands-on training. The educators in the field of HT have taken advantage of all these conventional methods.

In this study, a ubiquitous 360° learning environment (360° ULE) was developed on HT education and its effectiveness was evaluated through student satisfaction and HT knowledge. Furthermore, this study provides systematic and transparent information on the development process, which has previously remained unreported in higher education or in the HT context.
2 Theoretical framework

The theoretical framework is based on previous literature. The key concepts include ubiquitous learning, criteria of ubiquitous learning environments (ULE), histotechnology (HT), educational effectiveness and 360°technology. The theoretical framework is based on literature searches conducted in multiple phases during years 2013-2017. The searches focused on higher education, learning environment development, health and medical sciences, biomedical/medical laboratory science, pathology, histology, histopathology and HT, ubiquitous learning and learning environments, learning outcomes, and on assessment methods. The literature searches were conducted by using multiple search terms and combinations of terms. International databases such as ScienceDirect, ProQuest, PubMed and EbscoHost were used. Grey literature was searched by using web-browsers such as Google Scholar, Mozilla Firefox and Google Chrome. All relevant references are listed in the reference list.

2.1 Medical laboratory science and histotechnology

Medical Laboratory Science is the study of the scientific principles and disciplines practiced in hospital and medical research laboratories. It is a combination of health disciplines and technological understanding of diagnostics in clinical health care and an important link between healthcare professionals, diagnostics and the public. (IFBSL 2008, Andersen & Kjærgaard 2012.)

The professionals of medical laboratory science provide information from laboratory analyses, assisting physicians in patient diagnosis, disease monitoring, disease prevention and treatment. Educated professionals use technologies, instrumentations and methods to perform laboratory testing from blood, cell and tissue samples and body fluids. Laboratory testing includes disciplines such as clinical chemistry, hematology, immunology, immunohematology, microbiology, physiology, neurophysiology, cell and molecular biology, cytology and histology. (Australian Institute of Medical Scientists 1994, Metropolia 2016, ASCLS 2017.) Most of the Medical Laboratory Scientists (MLS) are generalists, skilled in all disciplines.

However, the qualification by unique education or additional training is possible in specific fields such as biochemistry, hematology, coagulation, immunohematology, microbiology, bacteriology, virology, parasitology, mycology, toxicology, immunology, histopathology or histology, histocompatibility, cytopathology, cytogenetics, electron microscopy and IVF (in vitro fertilization) labs.
The medical laboratory science profession has various career tracks based on the level of education and the regulations of different countries. The terminology used by different professionals is colorful. In the United States where the professions such as medical laboratory scientist (MLS), medical technologist (MT) and Clinical Laboratory Scientist (CLS) are known, the education of medical laboratory technician takes 2 years while the education of medical laboratory scientist takes 4 to 5 years (ASCLS 2017.) In Australia, medical laboratory scientists complete an education taking 3 to 4 years (Australian Institute of Medical Scientists 1994). In Finland the biomedical laboratory science degree program takes 3.5 years (210 ECTS) and leads to a Bachelor Degree (B.Sc.) and for registered qualification of BLS. The education is provided by the Universities of Applied Sciences (UAS) where around 230-250 students finish their BLS degree every year. At the end of 2016, there were 4150 members in The Association of Biomedical Laboratory Scientists in Finland. (2017.)

The International Federation of Biomedical Laboratory Science (IFBLS) has described the core competencies (IFBLS 2008, IFBLS 2011, Almås & Ødegård 2016) including the knowledge, skills, and abilities. The core competencies are the combination of knowledge, skills, abilities and attitudes, knowledge as a set of facts, principles, regularities and the success of adopting information, skills and activities in practice. (Ďurišová et al. 2014.) The required competences within the occupational standard expected are the following:

1. preparation and analysis of biological material,
2. correlation, validation and interpretation of the results,
3. reporting,
4. maintenance of equipment, device and supplies,
5. working safety,
6. continuous improvement of the services,
7. participation in education and training of other healthcare workers,
8. participation in research and development activities and in continuous professional development.

Histology is a study of the microscopic anatomy of various tissues (MeSH 2017). Histopathology is the microscopic study of diseased tissues. Histotechnology is the employment of histological techniques to diagnose diseases or conduct research. (NSH 2017.) Histotechnological (HT) knowledge is one of the core competences required from registered BLS. Education is a combination of theoretical knowledge and practical training focused on understanding the basis of pathological diseases,
on pathological basis of diseases, general and organ pathology, tissue morphology and practical skills needed in laboratory processes such as fixation, crossing, processing, embedding, sectioning, and staining, including quality assessment, legislation and working safety. In this study, the HT knowledge was summarized as pathological basis of diseases, normal cell structure and tissue morphology, tissue sampling techniques and HT laboratory processes as part of diagnosis and patient treatment. (Metropolia 2016, Turku AMK 2016, TAMK 2016.)

Learning HT has been strongly based on conventional methods such as lectures, information sharing, self-directed learning activities in digital learning management systems (LMS) such as Moodle and hands-on activities in HT laboratories. The learning has historically been based on a strong master-apprentice relationship (van Bodegom et al. 2013) and web-based online histology or histopathology courses have not been widely provided. No online courses can be found in Finnish but a few international courses were found in English (FutureLearn 2017).

Alongside the used conventional methods the educational institutions are heavily investing in digital technologies to support self-directed out-class activities and to facilitate the quality of learning. (Mahdizadeh et al. 2008, Liu & Hwang 2009.) Multiple devices, networks, software and applications are invading the students’ routines challenging the educational methods and practices, enriching learning effectiveness, expanding opportunities, enhancing learning satisfaction, reducing costs, helping teachers and motivating the students (Johnston et al. 2005, Rodriguez et al. 2008, Sivula 2011, Duque 2014, Dündar & Akcayir 2014, Schmid et al. 2014, Orus et al. 2016). However it should be remembered that each learning environment has its specific contents and the used methods can vary from the use of email and PowerPoint files (Collis et al. 2001, Ong & Lai 2006) to the use of scientific virtual laboratories (Potkonjak et al. 2016).

2.2 Ubiquitous learning environment

A learning environment can be any environment where the students can study and learn. It is a combination of different settings supporting the learning by utilizing technology in a pedagogically meaningful way. The learning environment can simulate the diverse authentic learning spaces with virtual and digital contents (Shear et al. 2011, Kankaanranta et al. 2012) and the learning can be supported by various technologies promoting the effective, personalized, interactive learning experiences regardless time or place. Learning is about changing, adopting new knowledge, skills and habits. Teaching is about helping learning. Learning can be
observed as a change in the behavior according to the behavioristic view. According to constructivists the individual's activity is seen as meaningful, while in socio-constructivism the meritorious social processes and the meaning of learning networks are underlined (Rauste-von Wright & von Wright 1994, Palinscar 1998, Siemens 2006). Together with improved learning outcomes, the purpose of teaching is to enhance critical thinking, problem solving, communication and co-operation by using relevant methods. (SchoolNet SA 2017, Griffin et al. 2012).

The descriptions and definitions of ubiquitous learning and ubiquitous learning environments (ULE) have varied and the terminology around the research area has been wide and colourful and have mixed with multiple phenomena such as mobile and augmented learning (McCall et al. 2011, Cheng & Tsai 2013). Distinguishing the differences between mobile and ubiquitous learning environments has been seen as challenging because of unconfirmed terminology (Yahya et al. 2010). In general, m-learning can be defined as any form of learning mediating through a mobile device (Alexander 2004). In educational use, mobile devices offer portability and ubiquitous access providing situated learning opportunities and changes the way to study and learn just-in-time. M-learning enables social interactivity and connectivity between individuals, devices, networks, and other technologies. (Melhuish & Falloon 2010). The first m-learning environments were published already in 2000 (Quinn 2000, Soloway et al. 2001), followed by descriptions of ubiquitous LEs (Ogata & Yano 2004). This study focuses on ULEs, which have not been widely studied or published in the higher education context. The differences between m- and u-learning environment have stated as context-aware and personalized learning activities with the use of functional objects, sensing technologies, mobile devices and wireless networks. Thus, the ULE is generally seen as a broader entity than the use of mobile devices in learning.

Ubiquitous learning environment (ULE) integrates the authentic learning space, omnipresent digital resources, functional objects, sensing technologies, mobile devices and wireless networks with the functional characters. It enables studying and learning on demand, based on students’ personal needs and own activity. ULEs are flexible, interactive, context-aware and personalized (Ogata & Yano 2004, Huang et al. 2008, Yahya et al. 2010, Hwang et al. 2011, Marinagi et al. 2013, Martin & Ertzberger 2013), learning resources provided in relevant location and time. (Sakamura & Koshizuka 2005, Hwang et al. 2008, Hwang et al. 2009, Yahya et al. 2010). Context-aware actions have been found as relevant (El-Bishouty et al. 2007) as well as the use of sensing technologies (Küpper 2005). Interactivity and collaboration have been reported as supportive for learning (Lin et al. 2005, El-Bishouty et
Personalized support and instructions have been seen as relevant (Johnston et al. 2005, Huang et al. 2012), and immediate feedback has promoted the effectiveness of learning performance (Zary et al. 2006, Huwendiek et al. 2009, Fonseca et al. 2015, Tsai et al. 2015). The lack of proper support has hindered learning (El-Bishouty et al. 2008, Miyata & Kozuki 2008, Hwang et al. 2011).

ULEs can be developed by using multiple technologies. The use of 360° technology is stated as one of the most interesting method of displaying education (Eye-revolution 2017). Viewers of 360° panoramic image become as a virtual participant immersed into observed scene, mimicking the real life learning environments within virtual environment allowing the users view the environment from different angles and directions. Included digital and functional objects transforms 360° panorama image from passive material on interactive learning resource where user can decide the actions currently played by navigation as rotating and zooming functions (Huang et al. 2008, Kwiatek & Woolner 2009, Ozkeskin & Tunc 2010).

The development or use of 360° panorama technology is not widely reported in educational use, instructional material and virtual tours in hotels and museums can be found (Bastanlar 2007, Louvre Museum 2007, Ozkeskin & Tunc 2010). Any research concerning the development or use in biomedical laboratory science or HT education context has not been published.

### 2.3 Educational effectiveness

The effectiveness of educational activities can be evaluated by using multiple models. The most famous models are the ones by Kirkpatrick (1998, 2006), Phillips (1997) and Kaufman (in Kaufman et al. 1995). Kirkpatrick’s (1998, 2006) four-level model is a widely used framework for objective evaluation of the educational settings. In the Phillips (1997) and Kaufman (in Kaufman et al. 1995) models the evaluation of investments and the effects on society have been included. (Fig. 1.)
As shown in Figure 1, according to Kirkpatrick the educational settings should be evaluated at least in the first two levels (Farjad 2012). Changes in practice, contribution for the organization, investments and impacts on costs may be evaluated in the organizational level. Impacts on the whole society should be assessed in a higher level, for example by the government. In this study, the evaluation focused on levels 1 and 2.

In educational settings, satisfaction can be understood in various ways and the various outcomes can be used in the evaluation of teacher's expertise, facilities, relevance of instructions, feedback, flexibility, convenience, self-directed opportunities, customized contexts, interactivity or enjoyment. (Looney et al. 2004, Eom et al. 2006, Jones & Chen 2008, Butt & Rehman 2010, Jung 2014.) The desirable level of satisfaction has been achieved when technology enhanced learning methods have been implemented in education (Sun et al. 2008, Ramayah & Lee 2012, Jung 2014). In this study, satisfaction was defined as 1) satisfaction on technological and 2) pedagogical aspects and 3) in instructions and feedback and 4) perceived enjoyment. In addition, the aspect of self-motivation was included. The level of satisfaction can be assessed by using multiple methods such as questionnaires, quizzes, observations and interviews. (Sun et al. 2008, Novo-Corti et al. 2013, Jung 2014.) In this study, the electronic questionnaire was used.
The changes in knowledge has conventionally been assessed or measured by using quantitative methods such as written tests, exams and practical testing. The testing has focused on numbers, grades and scores. (Coldwell et al. 2008, Fitzgerald 2008, Oermann & Gaberson 2009.) Versatile forms of assessment include multiple aspects (Norman et al. 2002, Bing-Johansson et al. 2013, Ďurišová et al. 2014) to ensure the subjective and objective perspectives. In the health education context, questionnaires and tests are commonly used (Polgar & Thomas 2008).

2.4 Summary of the literature

Learning is transferring out from the classrooms faster than ever, and any environment can be seen as a learning environment. ULEs are the new era of learning environments supporting seamless learning regardless of time and place. Flexibility, content personalization and context-awareness are perceived as necessities when digital learning environments are being developed. The meaning of interactivity, interaction and collaboration are seen as crucial.

An authentic learning space, omnipresent digital learning resources, functional objects, sensing technologies, mobile devices, wireless networks, social media tools and cloud-based approaches were combined in this study to build an effective learning environment for the students to learn about HT. The pathological basis of diseases, tissue morphology, sampling techniques and laboratory processes formed the context of this study and formed the basis of the evaluation of learning effectiveness. The level of student satisfaction was assessed from the technological, pedagogical, instructions, feedback and enjoyment points of view as a part of learning effectiveness. Figure 2 shows the theoretical framework of the study.
Fig. 2. Framework of the study.
3 Aim, research questions and hypotheses

The aim of this study was to develop a ubiquitous 360° learning environment (360° ULE) on histotechnology (HT) education and evaluate its effects on students’ satisfaction and on HT knowledge in biomedical laboratory science degree. In addition, the purpose was to provide systematic and transparent information on the development process based on the developmental and evaluation phases. The study answers the following research questions (RQs):

Developmental phase

1. What are the criteria for ULE in higher education context? (Article I)
2. How did the students perceive the use of ULE? (Article II)

Evaluation phase

3. How is the level of satisfaction assessed by the students and how does it differ between experimental and control groups? (Article III)
   Hypothesis 1: The level of satisfaction is higher in the experimental group than in the control group.

4. How has HT knowledge changed and differed among and between the experimental and control groups? (Article IV)
   Hypothesis 2: The HT knowledge is better in the experimental group than in the control group.

Hypothesis 3: There are significant interaction effects between groups and time.
4 Materials and methods

This study was conducted in two phases, namely development and evaluation with sub-phases. The phases were based on the Medical Research Council model for complex intervention development (MRC 2008), 1) with theoretical background, 2) piloting and feasibility testing 3) evaluating and optimization and 4) reporting and implementation. In this study, the MRC (2008) phases 1 and 2 were compounded as developmental phase and phases 3 and 4 as evaluation phase. (Table 1).

The developmental phase started by defining the criteria for ULE, and the framework for the development was built. The definitions for ULEs, previously reported development processes, outcomes and assessment methods were defined by using a scoping review method (Article I). Based on the results, the first version of ULE was developed by combining the following elements by using the 360° panorama technique:

1. authentic learning space (HT laboratory),
2. omnipresent digital learning resources,
3. functional objects used with sensing technologies and
4. mobile devices and wireless networks.

The 360° ULE was piloted in HT education. Student perceptions, positive effects and developmental needs were assessed and analyzed (Article 2). The results were reflected and minor changes were made. The optimized version of 360° ULE was used in the evaluation phase. The level of student satisfaction and the changes in HT knowledge were assessed (Articles III and IV). A detailed description of this study is shown in Table 1 and further described later in this chapter.
<table>
<thead>
<tr>
<th>Phase, research question and years</th>
<th>Design</th>
<th>Sampling</th>
<th>Data collection</th>
<th>Analysis</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development phase, Article I, 2013</td>
<td>Scoping review</td>
<td>Original publications fulfilled inclusion criteria</td>
<td>Original studies (n=7)</td>
<td>Content analysis</td>
<td>Criteria for ULE</td>
</tr>
<tr>
<td>Article II, 2014-2015</td>
<td>Quasi-experimental post-test design</td>
<td>All eligible BLS students (n=57) in one UAS, experimental (n=29) and control (n=28) group</td>
<td>Electronic questionnaire (n=24 items)</td>
<td>Explorative factor analysis, Mann-Whitney U-test</td>
<td>Student perceptions on the use of 360° ULE</td>
</tr>
<tr>
<td>2013-2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation phase, Article III, 2015-2016</td>
<td>Quasi-experimental pretest-post-test design</td>
<td>All eligible BLS students (n=115) in three UASs, experimental group (n=61) and control (n=54) group</td>
<td>Electronic questionnaire (n=27 items)</td>
<td>Content analysis, Mann-Whitney U-test</td>
<td>The level of student satisfaction</td>
</tr>
<tr>
<td>Article IV, 2015-2016</td>
<td>Quasi-experimental pretest-post-test design</td>
<td>All eligible BLS students (n=112) in three UASs, experimental (n=60) and control (n=52) group</td>
<td>Electronic questionnaire, knowledge test (n=45 items) and self-evaluation (n=68 items)</td>
<td>Mann-Whitney U-test, Wilcoxon test, two-way ANOVA</td>
<td>The level of student's HT knowledge</td>
</tr>
</tbody>
</table>
4.1 Developmental phase

4.1.1 The scoping review (Article I)

The aim of the scoping review was to identify the criteria and use of ULEs in higher education and to provide a wide view on the research area, provide an adequate knowledge base and point out the gaps in the existing literature. The literature review followed the Joanna Briggs Institute’s guidelines (JBI 2015). The review focused on determining the criteria for ubiquitous learning, learning environments, and to clarify the use of ULE (contents, components and outcomes). Systematical literature searches were conducted with the aid of the specialist of the medical library and were based on predefined inclusion and exclusion criteria, focused on ubiquitous learning and the previous use of ULEs in higher education contexts with quantitative study setting and participants such as university students, peers or academic staff members. The literature searches were conducted by using multiple international databases including health, nursing, medical, educational and pedagogical journals and limited to publication years between 2006-2013. The grey literature was not included in the final review. The titles (n=889), abstracts (n=78) and full texts (n=30) were independently screened by two researchers by using predefined inclusion and exclusion criteria. After the screening, the quality appraisal was performed for eight studies by following the JBI (2015) guidelines. The eligible original publications with high quality were selected and included (n=7) in the final review as shown in Figure 3.
An inductive content analysis was used for analysis. The extracted descriptions were listed and condensed from each study. Extracts were organized into subcategories and subsequently into final categories and the main categories. (Elo & Kyngäs 2008.) The results were reported by using the PRISMA Statement (Moher et al. 2009). (Article 1).

4.1.2 The production of 360° ULE

The ULE was produced custom-made by using multiple software. The 360° technique was selected based on the researcher’s vision and previous knowledge (El-Bishouty et al. 2007, Peng et al. 2008, Hwang et al. 2009, Hwang et al. 2011, Wu et al. 2011, Wu et al. 2012, Li et al. 2013). The need for flexible and interactive learning environment replicating real life learning situations was seen as a vital aspect. The costs, time consumption, agile development, easy use and content production were the criteria for the selected method.
The purpose was to produce the development method, which can be easily applied to various educational contexts by other educators. The 360° panorama was embedded with digital objects including texts, videos and audio files (Fig. 4). Selected learning resources were tagged on the panorama by using HTML5, CSS and JavaScript techniques to produce the user interface. (Article II.)

![Fig. 4. 360° panorama image with digital objects.](image)

Functional objects, quick response barcodes (QR), sensing technologies such as barcode scanners, wireless networks and mobile devices were included, as shown in Figure 5.

![Fig. 5. Functional objects in HT laboratory.](image)

The produced components, contents and contributors are described in Table 2.
Table 2. Component production and contributors.

<table>
<thead>
<tr>
<th>Component</th>
<th>Technology used in production</th>
<th>Contributor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authentic learning space</td>
<td>Histotechnology laboratory</td>
<td>Metropolia UAS &amp;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Researcher</td>
</tr>
<tr>
<td>360° panorama, user interface, icons</td>
<td>Adobe Lightroom, Adobe Photoshop, GardenGnome, Pano2VR, Kolor Autopano,</td>
<td>Visumo Ltd. &amp;</td>
</tr>
<tr>
<td>and control buttons</td>
<td></td>
<td>Researcher</td>
</tr>
<tr>
<td>Online webinars and video lectures</td>
<td>PTGui, HTML5, CSS, JavaScript</td>
<td>Researcher</td>
</tr>
<tr>
<td>Tutorials and demonstrations</td>
<td>Web conference system</td>
<td>Researcher</td>
</tr>
<tr>
<td>Video distribution</td>
<td>YouTube</td>
<td>Researcher</td>
</tr>
<tr>
<td>Assignments, tasks, exams</td>
<td>Moodle 2.7</td>
<td>Researcher</td>
</tr>
<tr>
<td>E-books</td>
<td>Electronic library</td>
<td>Metropolia UAS</td>
</tr>
<tr>
<td>Virtual microscope</td>
<td>WebMicroscope®</td>
<td>Fimmic Ltd &amp;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Researcher</td>
</tr>
<tr>
<td>Quick Response codes</td>
<td>Code generator</td>
<td>Researcher</td>
</tr>
<tr>
<td>Interaction with teacher and peers</td>
<td>Social media tools, Cloud applications, Web conferencing</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

The ULE was utilized with a mobile device (iPad2, Apple) provided by the UAS or could be used by any smart device with an internet connection. Interaction between teacher, students and peers was supported by using cloud-based approaches and social media tools.

The produced 360° ULE, the contents and the structure were evaluated by the experts and stated as relevant. The entity of 360° ULE is shown in Figure 6.
The web-based learning environment, WLE, was produced and managed in LMS (Moodle 2.7) and was provided as files and folders based on information sharing (Fig.7.). All of the same learning resources were presented as in the ULE.
4.1.3 The implementation of 360° ULE (Article II)

The first version of 360° ULE was produced and implemented in the HT context. HT knowledge was based on previous knowledge (El-Bishouty et al. 2007, Peng et al. 2008, Hwang et al. 2009, Hwang et al. 2011, Wu et al. 2011, Wu et al. 2012, Li et al. 2013) and curricula of different universities in Finland, US and New Zealand (NSH 2017, Metropolia 2016, Turku AMK 2016, TAMK 2016, Indiana University 2016, Tennessee University 2016, Otago University 2016). The learning objectives focused on 1) histotechnological processes as a part of diagnosis and patient treatment, 2) normal cell structure and tissue morphology, 3) tissue sampling techniques in theory and 4) laboratory processes of histological tissue sample. The weekly program was scheduled (Table 3.) and the intervention duration was set at eight weeks based on local curricula. The studies were divided in theoretical (3 ECTS) and practical (3 ECTS) parts. The theoretical studies included orientation, workshops, and the summative session.

<table>
<thead>
<tr>
<th>Week</th>
<th>Objective</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-III</td>
<td>Histotechnological processes as a part of diagnosis and patient treatment</td>
<td>Pathological basis of diseases</td>
</tr>
<tr>
<td></td>
<td>Normal cell structure and tissue morphology</td>
<td>Organ pathology, Neoplasms</td>
</tr>
<tr>
<td>IV-V</td>
<td>Tissue sampling techniques in theory</td>
<td>Tissue sampling, histotechnological processes</td>
</tr>
<tr>
<td>VI-VIII</td>
<td>Laboratory processes of histological tissue sample</td>
<td>Histotechnological processes, safety and quality management</td>
</tr>
</tbody>
</table>

The aim of the pilot study was to assess the student perceptions when 360° ULE was used and compared with conventional web-based learning environment. A quasi-experimental study design was used with experimental (ULE) and control groups (WLE) where the experimental group studied via 360° ULE (Fig. 6.) and control group via a conventional web-based learning environment (Fig.7.).

In the ULE group all learning resources and devices were in free use, and interaction was supported by using communicative tools. In the WLE group, the use
of 360° panorama image, functional objects, mobile devices, communicative tools or virtual microscopy were not present. The pilot study was performed in one UAS by the researcher. The students were eligible to participate if their studies had advanced as planned in the curriculum, with studies in anatomy, physiology, pathophysiology, laboratory methods, and mathematics completed before enrolment.

Participants

A total of 100 students enrolled in the HT course of which 57 students voluntarily participated in the experiment. The participants were divided in the experimental (n=29) and control (n=28) groups. 86 % of the participants were women, with an average age of 28.5 years. Significant differences in background information were not revealed between groups. The participants were divided in groups based on semester. The participants were informed of the used study protocol, resources and methods. Thus, participation took place with informed consent.

Data collection

The data was collected with questionnaire electronically in years 2014-2015. The student perceptions were assessed in the end of the study period by using the data collection instrument developed in this study (Article II). The criteria for ULE were used as a theoretical background for the instrument development (Article I). The instrument included 24 items and background information. All individual items were rated on a 5-Likert scale, from strongly agree (scored as 5) to strongly disagree (scored as 1). The instrument was based on the following variables:

1. flexibility (including possibility to study anywhere, anytime, on demand, just in time, omnipresent and permanent learning resources, high accessibility)
2. personalization (including information, learning content and time management including personalized learning content, self-paced time management, learning activities based on the learners’ own activity)
3. context-awareness (including embeddedness and use of functional objects including information provided on the learners’ request, controlled by the context such as user, time or location, use of functional objects, sensing technologies and mobile devices) and
4. interactivity (including collaboration and feedback and interactivity including collaborative and interactive learning methods supported with relevant tools and approaches)

The reliability of the instrument was examined by using Cronbach alphas for internal consistency. The construct validity was examined by exploratory factor analysis and the content validity by the experts. (Article II). The process of the instrument development is described in Table 4.
### Table 4. Data collection instruments

<table>
<thead>
<tr>
<th>Phase, Instrument, article</th>
<th>Factor/ Subscale</th>
<th>Items (n)</th>
<th>Scale</th>
<th>Reliability both groups(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development phase,</td>
<td></td>
<td></td>
<td></td>
<td>ULE(^a), WLE(^b)</td>
</tr>
<tr>
<td>students’ perceptions,</td>
<td>flexibility</td>
<td>4</td>
<td>Likert 1-5(^2)</td>
<td>.84(^1)</td>
</tr>
<tr>
<td>article II</td>
<td>personalization</td>
<td>5</td>
<td></td>
<td>.83</td>
</tr>
<tr>
<td></td>
<td>context-awareness</td>
<td>9</td>
<td></td>
<td>.76</td>
</tr>
<tr>
<td></td>
<td>interactivity</td>
<td>6</td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td>Evaluation phase,</td>
<td>pedagogical methods</td>
<td>6</td>
<td>Likert 1-5(^2)</td>
<td>.83</td>
</tr>
<tr>
<td>level of satisfaction,</td>
<td>technological methods</td>
<td>3</td>
<td></td>
<td>.61</td>
</tr>
<tr>
<td>article III</td>
<td>instruction and feedback</td>
<td>7</td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td></td>
<td>enjoyment</td>
<td>6</td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td></td>
<td>self-motivation</td>
<td>3</td>
<td></td>
<td>.64</td>
</tr>
<tr>
<td></td>
<td>positive aspects and developmental needs</td>
<td>2</td>
<td>open-ended</td>
<td></td>
</tr>
<tr>
<td>Evaluation phase,</td>
<td>pathological basis of diseases</td>
<td>45</td>
<td>max. score 60p(^3)</td>
<td></td>
</tr>
<tr>
<td>HT knowledge, test,</td>
<td>normal cell, tissue morphology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>article IV</td>
<td>HT laboratory processes, sampling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation phase,</td>
<td>pathological basis of diseases</td>
<td>68</td>
<td>Likert 1-5(^2),</td>
<td>.96(^a), .95(^b)</td>
</tr>
<tr>
<td>HT knowledge,</td>
<td>normal cell, tissue morphology</td>
<td></td>
<td>max. score 340p</td>
<td>.99 , .99</td>
</tr>
<tr>
<td>self-evaluation,</td>
<td>sampling</td>
<td></td>
<td></td>
<td>.99 , .98</td>
</tr>
<tr>
<td>article IV</td>
<td>HT laboratory processes</td>
<td></td>
<td></td>
<td>.96 , .97</td>
</tr>
</tbody>
</table>

\(^1\) Cronbach \(\alpha\), \(^2\) from 1 as totally disagree to 5 as totally agree, \(^3\) true- false, multiple choice, \(^a\) ULE, \(^b\) WLE
Data analysis

Data was analyzed by using IBM SPSS statistical software version 21 (SPSS, Chicago, IL). Non-parametrical, statistical tests were used to determine the differences in four subscales: flexibility, personalization, context-awareness and interactivity. Statistically significant differences between the experimental and control groups were examined by using Mann-Whitney U-test for independent samples. The p-value, <.05, was used to describe statistical significance.

4.2 Evaluation phase

The data from development phase was carefully analysed and reflected and the following minor changes were made in the final version of 360° ULE. The intervention duration was shortened from 8 weeks to 5 weeks. The technical usability was optimized by the programmer. The password protection in 360° ULE was removed.

Interactivity was strengthened by using cloud based approaches and social media tools such as Facebook, Google Drive and YouTube. All video files, tutorials and demonstrations provided were shortened to a maximum length of around 6 minutes per each video. Content in both interventions remained the same. The optimized version of the 360° ULE was implemented in the final study.

4.2.1 Level of satisfaction (Article III)

In the final study, the level of student satisfaction was assessed by using Kirkpatrick’s (2008) evaluation model (Fig. 1.). The aim was to assess the satisfaction regarding the use of the 360° ULE and compare it to the conventional WLE.

Participants

Totally 115 students, in three UASs (n=49/34/32), participated voluntarily in the experiment and were divided in the experimental, ULE (n=61) and control, WLE (n=54) groups. 82% of the participants were women, 18% men, and the average age was 27 years. Significant differences in the background information between groups were not revealed.
**Data collection**

The data was collected in years 2015-2016 by using an electronic questionnaire. The level of satisfaction was assessed in the end of the intervention by using the data collection instrument developed in this study (Article III). The assessment measured the level of students’ satisfaction, defined as technological and pedagogical satisfaction, satisfaction with instructions and feedback, perceived enjoyment and self-motivation assessed by the students (Article III, Table 2). These factors were used as sub-scales in data analysis. The assessment included background information, 25 items (Likert 1-5 scale) and two open-ended questions to determine positive aspects and the developmental needs of the learning environment (Appendix 1). The internal consistency was evaluated by using Cronbach’s alpha for the whole instrument, for all subscales, in both groups. (Table 4.). (Article III, Table 2.)

**Data analysis**

Data was analyzed by using SPSS statistical software version 21 (SPSS, Chicago, IL). The differences in subscales were examined by using non-parametrical statistical tests such as Mann-Whitney U-test to determine statistically significant differences between the groups. The level of statistical significance was set at p-value <.05. The open-ended questions were analysed by using inductive content analysis (Article III). The analysis was performed in three phases: preparation, organisation and reporting. In the preparation phase, the raw data was read multiple times and the findings were compared against the research questions. The analysis unit and formalized categories were defined. The sub-categories were formed and organized under the higher categories. The results were presented as charts and original citations (Article III, Fig. 5 and Fig. 6).

**4.2.2 Changes in histotechnological knowledge (Article IV)**

The aim was to assess the changes in HT knowledge within and between the experimental, ULE and control, WLE groups.

**Participants**

Totally 112 students, in three UASs (n=46/34/32), participated voluntarily and were divided in the experimental, ULE (n=60) and control, WLE (n=52) groups. 84 %
of the participants were women, 16% men, and average age was 28 years. Significant differences in the background information between groups were not revealed.

**Data collection**

The data was collected in years 2015-2016 by using electronic questionnaire. The level of HT knowledge was assessed by pre- and post-tests with the instrument developed in this study (Table 4.) (Article IV). The instrument was developed in iterative cycles with multiple experts as students, lecturers, medical laboratory technologists, specialists and pathologist. The learning outcomes were defined based on internal (n=3) and international (n=3) curricula of biomedical laboratory science (Article IV.) The learning outcomes were defined as follows:

- Histotechnological processes as a part of diagnosis and patient treatment
- Normal cell structure and tissue morphology
- Tissue sampling techniques in theory
- Laboratory processes of histological tissue sample

The instrument was divided in two sections, including knowledge test (n=45 items) and self-evaluation (n=68 items) (Table 4.) (Article IV, Figure 2, Appendix 2 and 3). Items for the knowledge test (n = 81) were formed by the researcher and critically evaluated by senior lecturer (n=1), pathologist (n=1), medical laboratory technologists (n=13), specialists (n=2) and students (n=5). CVI (content validity index) was computed and items lower than 0.78 (n=36) were excluded from the final instrument (Article IV, Fig. 2). The maximum score of knowledge test was set at 60 points. Items for self-evaluation (n = 153) were formed by the researcher and evaluated by medical laboratory technologists (n=9) and specialist (n=1). CVI was computed and 85 items were excluded from the final instrument (Article IV, Fig.2.). The maximum score of self-evaluation was set at 340 points, HT knowledge total as 400 points. The internal consistency was evaluated by Cronbach alphas’ for all subscales in both groups. (Table 4.)

**Data analysis**

The data was analyzed by using SPSS statistical software version 21 (SPSS, Chicago, IL.) The differences between groups were examined by using Mann-Whitney U and Wilcoxon tests. The two-way ANOVA was used to compare the mean differences between groups and time (pretest vs. posttest) and to understand the interactions
between the variables. Differences within the groups were tested by using Wilcoxon’s test. The level of statistically significant difference was set at p-value <0.05.
5 Results

The development phase answered research questions, RQ1 and RQ2. The results are reported in detail in the original articles I and II. The evaluation phase answered research questions RQ3- RQ4 and are reported in the articles III and IV.

5.1 Developmental phase

5.1.1 The criteria for ULE (Article I)

The criteria and reported use of ULE was summarized as a result of the scoping review (Article I, Table 1). All reviewed publications defined ULE as a combination of authentic learning spaces and digital environments, web-based learning management systems, use of functional objects, sensing technologies and mobile devices. (Article I, Table 3.) The main criteria were summarized according to flexibility including high accessibility and permanence, context-awareness including location basis activities and embeddedness, personalized learning content, information and feedback, and interactive collaboration with teachers and peers. Flexibility was noted in 7 publications, context-awareness in 6, content personalization in 7 and interactivity in 3 publications of the publications reviewed (n=7) (Article, Table 3.). All ULEs were developed for specific use in specific contexts such as nursing (n=1), language learning (n=2), chemistry (n=1), computing (n=2) and ecology (n=1). The measured outcomes focused on learning effectiveness in 6 publications, on cost-effectiveness in 1, on student satisfaction in 2 and on usefulness in 3 of the reviewed publications (n=7). Custom-made instruments were used in all studies to measure the outcomes. All included studies were experimental with participants as university students or academic staff. The study design used was experimental with comparisons in all publications. The most used data analysis methods were quantitative.

All reviewed publications indicated positive effects of ULE and the use was recommended as supportive for learning efficiency and better performance.

5.1.2 The students’ perceptions on 360° ULE (Article II)

The pilot study assessed student perceptions when the 360° ULE was used and compared them to perceptions when conventional WLE was used. Students in the
ULE group (n=29) assessed the use of LE as highly positive in all measured subscales. The overall mean was 4.3 (Likert 1-5). The highest estimations were given to personalization (mean 4.5) and context-awareness (mean 4.5). The flexible use of ULE was assessed lower (mean 4.1), the interactivity subscale as the lowest (mean 3.9). (Article II, Table 2.)

In the WLE group (n=28) the student perceptions on the use of LE were highly positive, with an overall mean of 4.4. The highest estimations were given to personalization, the mean being 4.5, and in context-awareness, with a mean of 4.6, which were also the highest in the ULE group. The flexible use of WLE was assessed lower, the mean being 4.3, and the interactivity as the lowest, with a mean of 4.1. (Article II, Table 2.)

The estimations given were higher in almost every subscale in the WLE group than in the ULE group. At any rate the differences between and among groups were very small in all subscales. Any statistically significant differences were not observed between the groups.

5.2 Evaluation phase

5.2.1 Level of satisfaction (Article III)

The final study assessed the level of student satisfaction and compared the differences between the groups in ULE (n=61) and WLE (n=54). The level of satisfaction was assessed as high in both groups. In the ULE group, the overall mean was 3.8 (Likert 1-5) and in the WLE group 4.0. In the ULE group, the students were most satisfied with the used technology, the mean being 4.2, and pedagogical methods that received a mean of 4.0. Lower satisfaction were assessed in enjoyment, mean 3.7, and self-motivation, mean 3.8. The students were most dissatisfied with items in instructions and feedback subscale, the mean being 3.6 for both. In the WLE group, students were the most satisfied also with the used technology, with a mean of 4.1, while the mean for pedagogical methods was 3.9. Also the instructions and feedback subscale was assessed as high, with a mean of 4.1.

The lowest estimations, in WLE group, were given in the enjoyment subscale that received a mean of 3.8. (Article III, Table 2.) The differences between groups were small in every subscale.
A statistically significant difference between groups was seen only in the instructions and feedback subscale (p>0.001) where the mean was 4.1 in the WLE group and 3.5 in ULE group. (Article III, Table 2 and Table 3.)

The results from open-ended questions revealed both positive aspects and developmental needs of ULE. The diverse, re-usable, flexible learning content, personalized and flexible timetables, and use of the digital learning resources were noted as positive aspects. In addition, the use of mobile devices and selected applications were described as relevant. Developmental needs were seen in technological usability and in instructions. The responses also revealed the need for more structured course planning, detailed instructions, general supervision and technical support. The detailed results are reported in Article III, Fig. 5 and Fig. 6.

Student satisfaction was hypothesized (Hypothesis 1) to be higher in the experimental group than in the control group. The results did not, however, support the hypothesis. Satisfaction was on a high level in both groups in all subscales but not significantly higher in the experimental group in any subscale.

5.2.2 Changes in histotechnological knowledge (Article IV)

The final study assessed the level of the students’ histotechnological (HT) knowledge at the beginning and at the end of the study term and compared the differences in HT knowledge between and within the ULE (n=60) and WLE (n=52) groups. All students within the ULE and WLE groups, scored significantly higher after the studies than before them (p<0.001) when pre-test and post-tests were used. The total HT knowledge was assessed as a sum of knowledge test and self-evaluation scores. In the ULE group, the total HT knowledge was 41% higher in the post-test than in the pre-test, and in the WLE group the scores were 37.5% higher. The knowledge test scores in the ULE group were 29 % higher and in self-evaluation 43 % higher in the post-test than in the pre-test. In the WLE group, knowledge test scores were 25% and self-evaluation scores 40% higher in post-test than in the pre-test. (Article IV, Table 3.)

A statistically significant difference was seen between the ULE and WLE groups in pre-test scores (p<.001). The ULE group scored 37% of total in the pre-test and 78% in the post-test. The WLE group scored 40% in the pre-test and 78% in the post-test. The changes between the pre- and post-tests scores and groups were statistically significant when pre-test and post-tests scores were compared. Changes in HT knowledge were significantly higher in the ULE group (p=0.05).
Statistically significant two-way interactions were revealed between the time and groups. The students’ HT knowledge improved significantly more in the ULE group than in the WLE group in relation to time (p=0.01). (Article IV, Tables 4 and 5.)

The HT knowledge was hypothesized (Hypothesis 2) to be stronger in the experimental group than in the control group. When the actual post-test scores were compared between the groups the results did not support the hypothesis. Significant differences between the groups were not revealed.

It was hypothesized (Hypothesis 3) that there are significant interaction effects between groups, time and used LEs. The results supported the hypothesis. Students in the ULE group scored significantly lower in the pre-test than the students in the WLE group, whilst in the post-test the ULE group scored significantly higher than the WLE group. The change in actual scores was significantly higher in the ULE group than in the WLE group. Significant interaction was seen between groups and time.

5.3 Summary of the results

The aim of this study was to develop a ubiquitous 360° learning environment on histotechnology (HT) education and evaluate its effects on student satisfaction and on HT knowledge in biomedical laboratory science degree. Development of 360° ULE was based on the criteria reported as the main result of the scoping review (Article I). Criteria such as flexibility, personalization, context-awareness and interactivity were perceived as necessities.

Based on the results, the 360° ULE was produced as a combination of authentic learning space, omnipresent digital learning resources, functional objects, sensing technologies and mobile devices. The 360° ULE was implemented and piloted in the HT context.

The results confirmed the positive perceptions when the 360° ULE was used in pilot study (Article II). Minor changes were done before the 360° ULE was implemented in the final study for the evaluation.

In the final study, the students in the experimental group were as satisfied with the use of pedagogical and technological methods as part of the new and innovative learning environment as the students in the control group (Article III). The HT knowledge improved significantly in both groups (p<0.001) when the pre-test and post-test results were compared. Students in the experimental group scored lower in the pre-test than the students in the control group. In the post-test, the differences
had disappeared and the changes in the scores between the groups were statistically borderline \((p=0.05)\). Significant interactions between group, time and learning results were revealed \((p=0.01)\) in the experimental group. (Article IV).

The results indicate that the use of ULE may enhance learning with high satisfaction but is not significantly more effective than conventional WLE. Student satisfaction was in the same level in the control group than in the experimental group or even higher in the control group. Based on these facts, the developed learning environment can be used as an effective learning method in the HT context (Fig. 8.) and should be developed further to confirm the results. The importance of systematic and transparent development and evaluation processes was highlighted as one of the main results of this study.

---

**Fig. 8. Summary of the results**

| Results (RQ1): |
The criteria for ULE as follows: flexible, personalized, context-aware, interactive.  
The view on the used ULEs in higher education. |
| Results (RQ2): |
Positive perceptions in flexibility, personalization, context-awareness.  
Developmental needs in interactivity and technological usability. |
| Results (RQ3): |
Students satisfaction in a high level.  
Satisfaction on pedagogical and technological methods as the highest.  
Significant differences in interactivity where control group more satisfied than experimental group. |
| Results (RQ4): |
HT knowledge increased significantly in both groups.  
Significantly stronger knowledge in experimental group than in control group.  
Significant interactions between time and groups. |
6 Discussion

6.1 Discussion of the main results

The development process was systematic, transparent and based on theoretical and empirical knowledge (Article I and II). All ULEs found from previous literature were custom-made for specific purposes and produced in universities without transparent reporting, practical implications or relevant possibility to reimplement (El-Bishouty et al. 2007, Peng et al. 2008, Hwang et al. 2009, Hwang et al. 2011, Wu et al. 2011, Wu et al. 2012, Li et al. 2013).

The produced entity can be stated as effective when compared to the results from the scoping review (Article I). Pervasive and seamless learning opportunities were provided and they were flexible with high accessibility. Context-aware and personalized learning contents were provided and controlled by the user or location. Interaction between teachers and peers were supported. (Article II.) The results confirmed that flexibility, personalization and context-awareness were at a relevant level. Clear objectives, personalized contents, detailed scheduling, information sharing and context-aware aspects were found as supportive for learning.

The results revealed critical developmental needs in the interaction between the teacher and students (Article II.) which have been stated as relevant also in the previous studies. Also the meaning of personalization, interaction and feedback have been stated as relevant (Johnston et al. 2005, Zary et al. 2006, Huwendiek et al. 2009, Huang et al. 2012, Fonseca et al. 2015, Tsai et al. 2015). The enhanced interaction, self-regulated learning situations, and the provision of personalized services have been described as undeniable benefits (Hwang et al. 2008, Ogata et al. 2008, Peng et al. 2008). Based on the previous studies the apparent lack of technological literacy among educators may interfere with the implementation critically. (Watty et al. 2016, Lewis et al. 2013.) Problems in technical usability may also cause problems. The resistance to innovation, lack of interest, preference of conventional methods, lack of resources and knowledge of technology have been listed as key barriers for successful implementation by Senik & Broad (2011). All these aspects were seen in this study.

The ULE was developed by using a number of experts, technologies, methods and approaches. The used 360° panorama technique was stated as very interesting and relevant for educational use. It has been reported as the most interesting method in current educational development and many companies in Finland and countries
worldwide are focused on these technologies in educational use. Thus, the selected technology for the development can be seen as relevant.

The results showed that the use of the 360° ULE improved the HT knowledge at the same time with the students’ high level of satisfaction (Article III). The increase of HT knowledge was stated as statistically significant in both groups when the changes in pre-test and post-test scores were compared (p=0.01). The statistically significant interactions between groups and time were stated in the experimental group (p=0.05). In the pre-test scores, significant differences were seen between the groups. The students in the ULE group scored significantly lower in the beginning than the students in the control group. In the post-test, the differences between the groups were leveled off. The interpretation of the results poses many challenges based on the non-linear nature of learning influenced by several factors such as motivation, learning style or underperforming. Based on these facts, the increased knowledge in the ULE group may have been caused by the bias and lead to critical misinterpretations. Due to the small sampling size, the results should not be seen anything more than indicative.

Satisfaction was seen as a relevant quality factor, similar to previous studies (Navarro et al. 2005, Mai 2005, Douglas et al. 2008). Defining and assessing satisfaction is a multidimensional issue which cannot be unambiguously explained. In this study, students were eager to use new technologies, enjoying adequate instructions, supportive guidance and instant feedback as also stated in Arbauch (2000) and Sun et al. (2008) studies where instructor feedback and timely response have influenced significantly on student satisfaction. The high quality of resources have increased student satisfaction and the use of learning material (Li et al. 2013). The distribution of versatile learning resources have been recommended in previous studies (Rodriquez et al. 2014) and the knowledge gaining has stated easier when a wide range of learning resources were provided. Therefore, the content production was versatile also in this study.

Although the students were highly satisfied with studying via the 360° ULE, the students were more satisfied when conventional WLE was used. The results might be explained by the increased cognitive load when new methods were used. In fact, significant interactions between increased cognitive load and use of new technologies have been reported in previous studies (Hwang et al. 2011, Wu et al. 2012).

When studying in digital environments rather than in conventional ones, more activity from the students’ part has been stated (Owston et al. 2013). The lack of
proper technological skills or resources may also slow down and interfere the learning processes. Also the lack of adequate information has been seen as a negative factor for learning effectiveness (Wu et al. 2012.)

6.2 Ethical considerations

This research was carried out according to the ethical guidelines and good scientific practices (Polit & Beck 2016, TENK 2012). The ethical values considered were privacy, anonymity, confidentiality, self-determination and fair treatment (Burns & Grove 2005). All experiments were carried out with the permission of the directors of the universities.

Students participated voluntarily and participation was confirmed by informed consent. The students were informed about the research objectives, contents, methods of data collection, analysing and reporting. In addition, students were informed about the course evaluation. They were also told that they can withdraw from the study at any time. The anonymity of individuals was ensured by using the student ID numbers. Names were not used at any phase. The identification of the individuals was not possible at any time. The collected data was treated and stored confidentially and password-protected. The data was analysed with the student ID numbers and the identification of individuals was not reported. After the final report, the raw data will be stored for five years before disclosure. All publications included in this study were published as original studies. Any conflicts of interest have been disclosed between the authors. The permission of republication of the original studies, as part of this summary, has been obtained.

6.3 Validity and reliability

The study was designed carefully to ensure the validity and reliability of the results. All original publications included are peer-reviewed by the international scientific committees and published without conflict of interest by the authors. The validity and reliability issues are discussed in detail in this chapter. More detailed validity and reliability interpretations can be found in the original publications, articles I-IV.
Developmental phase

The scoping review method was selected for the literature review. The method was suitable for scoping and summarizing the existing literature from the area not well known and in the area where the number of publications was limited. The literature searches were carried out systematically through predefined search criteria and search terms. The phenomena of ubiquitous learning and learning environment were included in the scope due to flexible possibilities to combine authentic learning space with digital resources, functional objects, sensing technologies and mobile devices. The m-learning environments were excluded based on the desire to study the phenomenon more broadly than from the view of utilized mobile devices or other implemented technologies.

In the systematical literature searches, no 360° implementations in the field of education were found. The searches were carried out with the aid of informatics of the medical library. Multiple international databases were used and the manual searches were done to obtain the most comprehensive search results. The relevance of the literature search process was stated as high. The gray literature was thoroughly searched but not included into the final review. Due to the very limited number of relevant references, the focus was set on high quality original publications. (Arksey & O'malley 2005.) The quality was evaluated by using Joanna Briggs Institute’s protocol for the scoping reviews (JBI 2015). The study with low quality score (>50%) were excluded (n=1) from the final review. The data analysis process was carried out by two researchers independently to reduce bias. Data extraction, preparation, condensation, and reporting were made by the researchers and verified with the research group. The reporting followed systematically the PRISMA framework (Moher et al. 2009). The systematically conducted review process ensured the high reliability of the scoping review results. Although the method used was regarded as very reliable, a few limitations were pointed out. The most relevant limitation in the scoping review was the number of eligible studies included, reported by the three sets of authors in two countries. The heterogeneity of the selected publications may interfere with the interpretations and cause a bias in the results. The not well-defined terminology of the ULE may hide relevant publications under other terms such as mobile or augmented learning. These terms were not searched, reviewed or analyzed systematically but were unofficially searched thoroughly during 2013-2017. Any publications describing the same kind of study design as in this doctoral study were not found during these years. Because of the delayed publication process systematical searches with the original search terms
were repeated in 2017. The search results did not differ significantly from the results in 2013 and thus no changes on the review were made. Although the sampling of the scoping review was modest and the number of eligible publications low, does not cause significant harm for the learning environment development or interfere significantly with the interpretation of the results.

The used 360° technology can be seen as a limitation in this study. The method was selected based on the researcher’s vision and on the simple, fast and cost-effective development process simulating real world learning situations as well as possible, managed by the educators. These requirements led to the decision that the possibilities of augmented or virtual reality methods were not systemically evaluated. Other relevant methods that educators could quickly and easily produce and implement were not found during the years of research. This is why the development of virtual worlds or virtual simulations were not in the scope at any phase. Moreover, the virtual world development was seen as very time-consuming and costly, and the researcher or the research group did not have the necessary skills required for the development. The aim of this development process was to provide a low-threshold method for the educators to implement 360° ULE easily in any educational context in higher education. For that purpose, the used method was stated as appropriate. For the same reason, the game-based learning environments (GLE) were not included. The development of GLE requires much more knowledge than the health science educators can be expected to have. The purpose was to develop versatile LE combining authentic learning spaces with flexible, interactive and context-aware digital environment, not to develop a GLE.

The context, content and the entity of 360° ULE were developed by the researcher also an expert of the HT and were confirmed by the research group. The dominant role of the researcher in development process can be seen as a limitation and might lead on misinterpretations. The researcher did not have a particular reason to emphasize the meaningfulness of the chosen 360° technology and she does not gain any economic benefits of the development process.

The study design was selected based on the used teaching methods. Study designs comparing ubiquitous and conventional methods have not been widely published (Aljohani et al. 2012). The conventional WLE was used as a control group. The intention was to refresh the web-based learning methods using the 360° ULE, not to replace widely used conventional, lecture-based methods. The purpose was not to replace conventional lecture based teaching methods as students seem to be quite satisfied with the use of conventional methods. The need for teacher-centered
lectures is still present but can be evolved with innovative and ubiquitous possibilities. The web-based self-directed learning activities have become dominant in many UASs. This was the main reason for the use of WLE in the control group. Additionally, the selection was based on the fact that the researcher has used conventional web-based LEs and methods for years.

**Evaluation phase**

A non-randomized quasi-experimental study design was selected as a method for the pilot and the final study. The method has been widely used in health science education (Campbell *et al.* 1966, Fraser *et al.* 2011). The study design was used without the randomization of individuals, whole groups were enrolled into experimental or control groups by the semester. The division was done to avoid any experiences of inadequacy by the students, and to reduce the possible bias between the groups if the LEs had been used alongside each other. Randomization is recommended to reduce the bias caused by the researcher, participant, instrument, data collection or analysis (Schulz & Grimes 2006).

The researcher carried out all experiments, data collections and analyses with the aid of the research group and the specialists to reduce potential bias and misunderstandings. The role of the researcher was as an educator and researcher without seeing a major contradiction between the roles. The students in any participating university were not familiar with the researcher beforehand.

The number of participants was seen as a major limitation of this study and may cause bias toward results and interpretations. The number of participants was limited to the number of students in the degree programs of biomedical laboratory science in Finland. Due to the small number of possible participants, the final study was conducted in three UASs, between the years 2015 and 2016, to reach a proper sample size, representing the whole population as well as possible. Another option for proper sampling would have been to prolong the data collecting time, which was considered effective. Data collection would have been easier in any other field of health science, where the number of students is considerably higher e.g. nursing, than in biomedical laboratory science. This option was not considered viable as the researcher's strongest competence was in the field of histotechnology and thus the development, production and implementation would have been impossible in any other contexts.

The unique practices of each UAS were seen as a limitation. Local practices, knowledge, skills, attitudes, motivation and previous level of technology may have
differed between UASs and may have interfered the results. The differences between universities were evaluated by the experts, following good scientific practices. No significant differences between the UASs were observed in the curricula, learning objectives or contents. However, the sample size represented the study population moderately and thus the results can be stated as indicative. To strengthen the results it is recommended to repeat the study with a larger population in one UAS.

The instrument development formed a large part of this research. Several experts such as students, senior lecturers, principal lecturers, biomedical laboratory technologists and pathologists assisted the researcher in the instrument development. The background for all instruments was systematically formed by previous literature. The reliability and validity of all instruments were evaluated by using multiple statistical methods. The construct validity was evaluated by using exploratory factor analysis, and reliability by using Cronbach’s alpha to measure internal consistency. In all instruments, the alphas were between 0.61 and 0.99. (Table 4). Almost all alphas were in the accepted level when the criteria was set on 0.70 (Connelly 2011, Tavakol & Dennick 2011.) Two alphas were lower than 0.70 (0.61 and 0.64) but did not critically affect the final results. Content validity was assessed by calculating the content validity index, CVI. The CVI was based on expert ratings of item relevance and the items lower than 0.78 were excluded. (Polit et al. 2007.) Content and construct validity as well as internal consistency were assessed in all instruments. All data collection instruments were developed in this study and were used the first time. This was seen as a limitation. However, the validity and reliability of the instruments were assessed as high. The first time use may cause a bias in the results.

All used instruments were questionnaires. The assessment of perceptions, satisfaction and knowledge were based on scores. More objective research methods such as interviews or observations were not used which can be seen as a limitation. The observations or interviews were not used. As the researcher conducted the learning environment development, content production, quasi-experimental interventions, data collection and analyzing in three UASs during the years 2014-2016, observation activities were not reasonably well included. The observation would have taken an unreasonable amount of time as 172 students in total participated in the study in different phases. To ensure objective assessment, open questions and self-assessments were used. To gain a broader perspective on the research area more objective research methods should have been utilized.
The data collection and analysis were made by the researcher with experts and were confirmed by the research group to reduce bias. Nonparametric, statistical tests were used to determine the main effects of independent variables, differences between and among the groups and interactions between independent and dependent variables. The data analysis methods were versatile and the method selection was carried out by the researcher and verified by the research group. Due to the large scale of the used methods, the validity and reliability of the pilot and final study were considered high.

As a conclusion, the research target was seen as challenging. Firstly, existing research in the context of the study was very limited. Secondly, previous use of ULE in higher education and HT context was nonexistent. Thirdly, the selected 360° technology had not been utilized previously in educational use. Finally, the phenomenon of ubiquitous learning or the concept of ULEs were not widely known.

6.4 Contributions and practical implications

This study highlighted the unique entity of 360° ULE in educational use. It demonstrated the slowly increasing popularity of ULEs in higher education. The systematic process provided a logical framework for the development and evaluation and generated new scientific knowledge to support educators in the future. The study provided insight into technological constructs and key factors of effective learning environments, and provided a concrete example.

For students the 360° ULE offered flexible opportunities to study and learn in real-life learning situations digitally, regardless of time and space. Students increased their histotechnological knowledge in an easy-to-use environment with high motivation and satisfaction. The feedback from students was encouraging and should lead to continuous development and use in the future. For educators, it offers new perspectives on pedagogical development.

For the health care organizations, the use of 360° ULE may offer talented students in the future. Real-life learning situations may be used to support student’s orientation in their work placements. The 360° ULE can be implemented in work-life environments and effect on coaching patterns of work life in the future.

For the society, the use of ubiquitous learning environments may provide effective and flexible possibilities to rearrange and widen the higher education. Reduced resources can be targeted more accurately by using novel methods to support learning activities. Globally, the development of ULEs can support education export and build up new clusters of knowledge in higher education development. The
use of ULE rearranges learning environments and provides positive learning experiences and performance with almost equal student satisfaction compared to conventional methods.

Although the research was performed in the HT context it is recommended to implement 360° ULEs also in other contexts in higher education. Based on the results of this study, the 360° ULE has already been implemented in degree programs of radiography, oral health and midwifery in Helsinki Metropolia UAS. The implementations have been made by following the development process of this study.
7 Conclusions

This section provides conclusions for this dissertation with detailed recommendations based on the results. In addition, it offers recommendations for future studies. Below is a list of the most important findings and observations of this study:

1. The criteria for ULE were summarized as flexibility, context-awareness, personalization and interactivity.
2. The relevant components of ULE are the following: authentic learning space, omnipresent digital learning resources, functional objects, sensing technologies, mobile devices and wireless networks.
3. The 360° ULE showed its pedagogical potential and significant benefits for students. It can be used as supportive for learning, and results as indicative for future development.
4. Student satisfaction with the use of 360° ULE was at a high level.
5. The use of 360° ULE may enhance learning and increase students’ HT knowledge.
6. The process was described transparently to guide educators in learning environment development. The study offers a practical example on successful implementation.

Based on these observations and findings, the following subsection sums up the most important recommendations.

7.1 Recommendations

The conclusions form a basis to six recommendations of which four require action and two refraining from action. Based on the results I recommend:

1. that conventional WLEs based on information sharing will be transformed to flexible, personalized, interactive and context-aware ULEs in the future.
2. that the developed 360° ULE will be adopted permanently in HT curricula to provide supportive, effective and diverse learning experiences.
3. further studies to strengthen the results including larger study populations in the HT and other health science contexts.
4. further development and optimization of ULE to ensure the interaction, including feedback and instructions, between teacher, students and peers.
Based on the results, I do not recommend

1. total replacement of conventional methods.
2. any rearrangements in practical training or hands-on activities.

### 7.2 Future studies

The developed 360° ULE showed its pedagogical and technical potential with significant benefits for the students, teachers and educational organisations. Thus, further studies and development should be encouraged as follows. The future studies should validate the developed instruments in a larger study population in HT contexts. The study should be replicated to ensure the results and to increase credibility. Interactivity between teachers, peers and students should be supported more carefully by using cloud based tools, social media and other relevant approaches.

Implementation in other health science contexts is recommended in the future. The developed 360° ULE can be utilized in any educational context in any level of education from elementary to continuous education. The pedagogical benefits can be ensured in various contexts by following the development process described in this study.

Further studies will be needed also to ensure national and international generalization. After validation, the developed 360° ULE can be implemented in the internal and international curricula in the histotechnology context.

The most interesting aspect in future studies relates to the utilization of the 360° ULE in a histotechnology laboratory as a part of real life processes where the learning transfer can be supported.

From the technical view, the development should be expanded with augmented reality learning and game-based activities. The utilization of functional objects and sensing technologies should be supported more systematically. The future studies may focus on the use of RFID tags and Bluetooth options to support more seamless interaction between the students, learning resources and authentic learning space.

### 7.3 Closing words

Conducting a doctoral thesis successfully in five years at the same time while pursuing a challenging career and living out active family life was a demanding task, but one that will hopefully inspire colleagues and co-workers in educational and academic institutions, companies and health care, in many ways.
This study project has relevance for the different stakeholders when changing conventional teaching and learning processes towards innovative, flexible, personalized, context-aware and interactive learning experiences with high satisfaction and effectiveness.

To sum up, the doctoral thesis was a turning point in my career as an educator and pedagogical expert. This process aspires to encourage educators worldwide to evaluate their own operations in relation to present possibilities.
References


TENK (2012). Finnish Advisory Board on Research Integrity. Responsible conduct of research and procedures for handling allegations of misconduct in Finland. Guidelines of the Finnish Advisory Board on Research Integrity.


Appendices

Appendix 1. Data collection instrument for assessing the level of students’ satisfaction

Instructions and feedback (Likert 1-5)
LE was technically easy to use
The learning material was clear
The learning material was interesting
The learning material was supportive
The instructions were clear
The role of teacher was supportive
The use of LE was supportive

Pedagogical methods
The methods used allowed deep understanding
The methods used provided challenges
The methods used gained learning
The assignments used supported learning
The contents were practical
Multiple teaching methods were used

Technological methods
The used methods were innovative
The used methods were up-to-date
The used devices were supportive

Perceived enjoyment
Satisfaction with implementation
Satisfaction with studies in general
Expectations fulfilled
LE was useful
LE eased my studying
Use of LE suggested to other courses

Self-motivation
LE motivated learning
I was actively responsible of my studies
Interest towards occupation increased

Open-ended questions
The positive effects of used ULE
The developmental needs of used ULE
Appendix 2. The knowledge test for histotechnology

Individual items in Finnish, not translated in English at any phase.

**Pathological basis of diseases**
Bronkoskopia on.. (multiple choice)
Ihon koepaloissa marginaali on merkityksellinen. (true-false)
Ihonäytteitä merkitään lankamerkeillä.. (multiple choice)
Ihon koepalan ei tarvitse yltää ihonalaiseen rasvakudokseen, ollakseen edustava. (true-false)
Karkeaneulanäytteitä ei voi ottaa sisäelim istä (maksa, perna, haima, munuainen). (true-false)
Rinnasta voidaan ottaa.. (multiple choice)
Rinnan muutosten diagnosointiin suositellaan karkeaneulanäytettä. (true-false)
Mastektomia tarkoittaa.. (multiple choice)
Leikkauşpreparaatit.. (multiple choice)

**Histotechnological processes**
Kudosnäytteen prosessi kestää nopeinnin 2-3 päivää? (true-false)
Pikatutkimuksena (jääleike) tehtävällä näytteellä diagnoosi saadaan puoleessa tunnissa? (true-false)
Pikatutkimuksen indikaation on.. (multiple choice)
Histologinen diagnoosi perustuu valomikroskopiaan? (true-false)
Histologisen kudostutkimuksen indikaatiot ovat.. (multiple choice)
Negativinen löydös poissulkee pahanlaatuisen löydöksen mahdollisuuden? (true-false)
Benigni muutos ja sen diagnosointi pois sulkee malignin muutoksen mahdollisuuden? (true-false)

**Normal cell and tissue**
Mikä kudos? n=6 (image + multiple choice)
Mikä rakenne? n=2 (image + multiple choice)
Mikä värijää? n=2 (image + multiple choice)
Hematoksyliini toimii sytoplasmavärinä (true-false)
Eosiini toimii sidekudosvärinä (true-false)
AB-PAS värijäästä käytetään.. (multiple choice)
Laboratory processes
Fiksatiivin tarkoitus on.. (multiple choice)
Formaliinifiksaatiota voidaan nopeuttaa viileässä. (true-false)
Patologin makroleikkelee.. (multiple choice)
Bioanalyyttikko makroleikkelee keskisuuria prepaatteja. (true-false)
Näytteiden käyntiinpanossa on tärkeää.. (multiple choice)
Kudosprosessoinnin tarkoituksena on.. (multiple choice)
Valun tarkoituksena on.. (multiple choice)
Mikrotoimilla kudosleikettä leikattaessa on tärkeää, että.. (multiple choice)
Kudosleikkeiden parafiini poistetaan ennen kudoksen värjäystä. (true-false)
HE-värjäys on kolmen värin värjäysmenetelmä. (true-false)
vanGieson-värjäys toimii.. (multiple choice)
Giemsa-värjäystä käytetään helikobakteerin osoittamiseen. (true-false)
Formaldehydi ei ole karsinogeeni. (true-false)
Appendix 3. The self-evaluation instrument for histotechnological knowledge

Pathological basis of diseases (n = 18)
Histotechnological processes as a part of diagnosis, incl. tissue sampling (n = 8)
Normal cell and tissue morphology (n = 23)
Laboratory processes for histological sampling (n = 19)

Individual items in Finnish, not translated in English at any phase.
1. perustella histologian merkityksen potilaan kokonaishoidossa
2. histologian merkityksen tautien diagnostiikassa
3. nimetä eri näytetyypit
4. selittää näytteenottomenetelmät
5. ymmärtää näytteenottomenetelmien merkityksen laboratorioprosessille
6. selittää histologisen kudosnäytteen vaihe vaiheelta
7. fiksation periaatteet ja merkityksen
8. selittää dissektion ja näytteiden käynnistämisens teoriassa
9. kuvata kudosnäytteen lähetteeseen
10. tunnistaa dissekoinnin virhelähteitä
11. tarkastella näytteen makroskooppiesti (teoriassa)
12. kudosprosessoinnin periaatteet
13. ymmärrän kudosprosessoinnin merkityksen näytteelle
14. ymmärrän valun merkityksen
15. tunnistaa valussa tapahtuvia virheitä
16. arvioida valun laatu
17. selittää eri mikrotomien toimintaperiaatteet
18. arvioida leikkeiden laatu
19. tunnistaa leikkaamiseen liittyviä virhelähteitä
20. HE- värjäyksen periaatteet
21. tunnistat osoitusvärjäysten käyttötarikoituksen valinnan periaatteet
22. PAS-värjäyksen periaatteet
23. AB-PAS värjäyksen periaatteet
24. arvioida HE- värjäyksen laadun mikroskoopissa
25. arvioida PAS- värjäyksen laadun mikroskoopissa
26. arvioida HE- värjäyksen laadun mikroskoopissa
27. arvioida AB-PAS- värjäyksen laadun mikroskoopissa
28. immunohistokemian merkityksen diagnoosissa
29. pika-/jääleikkeiden merkityksen diagnoosissa
30. ymmärrän histologian merkityksen obduktion osana
31. ymmärrän työturvallisuuden merkityksen yksityiskohtaisesti prosessin eri vaiheissa
32. sisäisen laadunarvioinnin periaatteet
33. ulkoisten laadunarviointikiertojen merkityksen
34. tunnistan työturvallisuusriskejä
35. tunnistan mikroskoopissa maksan, histologisen näkymän perusteella
36. tunnistan mikroskoopissa munuaisen, histologisen näkymän perusteella
37. tunnistan mikroskoopissa sydämen, histologisen näkymän perusteella
38. tunnistan mikroskoopissa keuhkon, histologisen näkymän perusteella
39. tunnistan mikroskoopissa ihon, histologisen näkymän perusteella
40. tunnistan mikroskoopissa ruoanasulatuskanavan epiteelin, histologisen näkymän perusteella
41. tunnistan mikroskoopissa HE-värjäyksen
42. tunnistan mikroskoopissa PAS-värjäyksen
43. tunnistan mikroskoopissa vG/Herovici värjäyksen
44. tunnistan mikroskooppisesti leveyepiteelin
45. tunnistan mikroskooppisesti rauhasepiteelin
46. tunnistan mikroskooppisesti sidekudoksen
47. tunnistan mikroskooppisesti rasvan
48. tunnistan mikroskoopissesti ruston
49. tunnistan mikroskooppisesti laskimon
50. tunnistan mikroskooppisesti valtimon
51. verenkierron anatomian ja fysiologian
52. verenkierrron häiriöiden mekanismit
53. tulehdusten aiheuttamat reaktiot teoriassa
54. solun sisäiset kertymät teoriassa
55. solun sopeutumismekanismit
56. solujen vaurioitumisen mekanismit
57. solujen kuoleman mekanismit
58. paranemisen mekanismit
59. kasvaintautien ominaispiirteet
60. karsinogeneesi
61. kasvainten nimeämisen periaatteet
62. elimistön kudos- ja solutyypit
63. sydämen rakenteen ja toiminnan
64. hengitysteiden rakenteen ja toiminnan
65. ruoansulatuskanavan rakenteen ja toiminnan
66. maksan rakenteen ja toiminnan
67. munuaisen rakenteen ja toiminnan
68. ihon rakenteen ja toiminnan
Original publications


Reprinted with permission from Springer International Publishing AG (article I, III and IV) and Taylor and Francis (article II).

Original publications are not included in the electronic version of the dissertation.
1440. Hagnäs, Magnus (2018) The association of cardiorespiratory fitness, physical activity and ischemic ECG findings with coronary heart disease-related deaths among men
1441. Huhtaniska, Sanna (2018) The association between antipsychotic and benzodiazepine use with brain morphology and its changes in schizophrenia
1442. Sundquist, Elias (2018) The role of tumor microenvironment on oral tongue cancer invasion and prognosis
1449. Kajula, Outi (2018) Periytyvän rintasyöpäalttiusmutaation (BRCA1/2) kantajamiehen hypoteettinen perinnöllisyysneuvontamalli
1452. Capra, Janne (2018) Differentiation and malignant transformation of epithelial cells: 3D cell culture models
1453. Panjan, Peter (2018) Innovative microbioreactors and microfluidic integrated biosensors for biopharmaceutical process control
1454. Saarela, Ulla (2018) Novel culture and organoid technologies to study mammalian kidney development

Book orders:
Granum: Virtual book store
http://granum.uta.fi/granum/
Mari Virtanen

THE DEVELOPMENT OF UBIQUITOUS 360° LEARNING ENVIRONMENT AND ITS EFFECTS ON STUDENTS’ SATISFACTION AND HISTOTECHNOLOGICAL KNOWLEDGE