Role of Multidisciplinary and Interdisciplinary Education in Computer Science: A Literature Review

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Disruption of economies, caused by the Internet and communications technology and its effect to other industries, has had and will continue to have severe effect to the existing business models and production of goods for the upcoming decades. In addition, increasing complexity of global problems calls for the need of new problem solving competences. Complex problem solvers, knowledge workers, are more and more working by collaborative structures, where the solution creation benefits from multiprofessional way of working. This study is focusing on a trend of how higher education, especially in the area of computer science and engineering, is responding to the challenge of educating collaborative knowledge workers to a knowledge intensive work environment. The study was performed by a literature review covering publications indexed by the Scopus bibliographic database to find relevant research articles and reviews published between the years 2000 and 2016. The results indicate a steadily growing interest towards multi- and interdisciplinary education. Most of the interest is indicated among the health care, medicine and nursing, and social sciences disciplines, while the interest among engineering and computer science is a clear minority. The results of this article can be used to study further the unused potential of engineering and computer science for the multi- and interdisciplinary education.

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Introduction

Globalisation and urban cities as hubs for economical development is a well-recognised phenomenon (e.g. Turunen 2015). In addition, the on-

going shift from an economy based on physical inputs, land, capital and labour, to an economy based on intellectual inputs, or human creativity (Florida 2006) requires new ways of solving problems. By the collaboration of multiple stakeholders, defined as persons or parties with an interest at hand (Freeman 1984), human beings are expected to co-create new knowledge when collaboratively facing present complex societal problems. Within this collaboration multi-cultural, multi-disciplinary and multi-generational approach is often proposed to be an improved way of complex problem solving.

Complex and intangible problems solvers, so-called knowledge workers, are supposed to be lifelong learners who continually acquire and develop new knowledge. They must be able to critically select, acquire and use knowledge, wherever this is available (Engeström, Engeström, and Kärkkäinen 1995; Konkola et al. 2007) and by continually constructing and reconstructing their expertise in a process of lifelong learning (OECD 1996; Tynjälä 1999). In addition to their disciplinary skills the knowledge workers are expected to master and develop metaskills. Metaskills, such as learning by utilising networks, communication and critical thinking, have become as essential as discipline-specific skills. Individuals possessing these skills are exposed to the experience and the knowledge of other disciplines and thus are recognised as carrying the skills for knowledge creation (Nonaka and Takeuchi 1995) and crossing boundaries. Boundary crossing competence is defined to be the 'ability to manage and integrate multiple discourses and practices across different sociocultural boundaries' (Akkerman and Bakker 2011; Lansu et al. 2013; Umemoto 2001; Walker and Nocon 2007) and the ability to function competently in multiple contexts (Walker and Nocon 2007).

During the past decades the role of Internet and communications technology (ICT) in our society has increased significantly. The effect ICT has on businesses and to our daily life is often referred as a digital disruption (Koiranen, Räsänen, and Södergård 2016; Degryse 2016), which often means the use of ICT to change business models, as well as provide new revenue and value to companies and organisations. The digital disruption affects all industries and aspects of life whether it is the use of social media to increase sales or the use of emails to stay in contact with business partners and friends. As a summary, ICT is being used in all business sectors to provide added value for the companies. Realising above, the role of ICT in changing industries should be taken into account also in higher education, not just in the fields of computer science

and engineering education. Also the opposite, since based on authors' background and experience, we claim that the computer science and engineering education would benefit greatly by the influence of other disciplines.

Higher education institutions globally have a significant role for educating new knowledge workers. Higher education is defined as an optional final stage of formal education that occurs after the completion of secondary education and is usually realised at universities, academies, colleges, seminaries, and institutes (UNESCO 1998). These education institutions are supposed to develop their education of knowledge workers towards to the needs of the surrounding society. Drawing together the society needs towards knowledge workers competences and growing utilisation level of ICT in other industries, the research questions in this article are defined as RQ1: 'What is the trend of interest towards multidisciplinary and interdisciplinary education in higher education?' and RQ2: 'Which disciplinary areas utilise the interdisciplinary and multidisciplinary in their higher education the most?' Main target for the research study in this article is to find and suggest topics and areas within the theme of multidisciplinary higher education for further research. In this article by the following chapters the terminology and methodology of the study, study results and the conclusions including further study proposals are described.

Definitions of Collaborative Activity

Definition of the collaboration between different professions or disciplines varies. The term 'disciplinarily' describes a somewhat traditional view of the academic discourses and is used to describe academic disciplines as autonomous and discrete areas of study. Across the disciplines independent academic communities rarely cooperate or coordinate their academic efforts. Academic disciplines, from this perspective, are discrete 'boxes,' albeit with boundaries that may be permeable (Davies and Devlin 2007). The problem over time with the traditional notion of the academic discipline is that disciplines are not historically fixed; instead they evolve and change over time (Squires 1992). Academic disciplines are culturally and historically situated, are also defined by many attributes, and the relative emphasis on these different attributes can differ from discipline to discipline, even within each discipline (Davies and Devlin 2007). Traditionally healthcare has been the academic discipline utilising professional collaboration. The concept of health incorporates a complex and

holistic system where biological, psychological, physical, socioeconomic, cultural, and environmental factors function as interconnected and interacting determinants of one another (Weiss et al. 2018). Collaboration, defined as two or more people involved and engaged in interaction with each other, within a single episode or series of episodes and working towards common goals (Patel, Pettitt, and Wilson 2012), definitions used often in a work context are interprofessional, interdisciplinary and multidisciplinary collaboration.

Interprofessional refers to a collaboration using several professionals that are collaborating with each other. It can be pretty simple, for instance in the case of healthcare interprofessional education 'involves educators and learners from 2 or more health professions and their foundational disciplines who jointly create and foster a collaborative learning environment. The goal of these efforts is to develop knowledge, skills and attitudes that result in interprofessional team behaviours and competence' (Buring et al. 2009; D'amour and Oandasan 2005.) Ideally, you can have a patient that is accessing different services and they may speak to each other to agree on a care plan. Interprofessional connotes the working relationship of people who have differing areas of professional expertise.

Multidisciplinary has been described more simply as the view that: 'everyone [does] his or her thing with little or no necessity for any one participant to be aware of any other participant's work' (Petrie 1976). Multidisciplinary is the co-existence of a number of disciplines. It is no more intellectually, or academically, illuminating than what typically exists in higher education degrees. In health care, multidisciplinary isn't just a collaboration of random professionals but a system, which creates good outcome for patients by utilizing different healthcare disciplines. In education, multidisciplinary recognises the fact that there are many discrete and autonomous disciplines. While students normally specialise in one discipline, they can study several over the course of a typical degree program. (Davies and Devlin 2007). For example, in addition to accounting subjects, an accounting student also studies some subjects in finance, and may also study some economics, and/or disciplines such as history or music.

Klein (1990) distinguishes interdisciplinary from multidisciplinary as more than one discipline working on the same problem, but with no real conversation. Interdisciplinary is a model not just random professionals speaking to each other, rather it refers to the combination of more than one area of knowledge. Unlike multidisciplinary, where disciplinarians

need not discuss things with each other, this variant requires 'more or less integration and even modification of the disciplinary sub-contributions while an inquiry is proceeding' (Davies and Devlin 2007). Different participants need to take into account the contributions of their colleagues to make their own contribution (Petrie 1976). In the health care this model is inclusive to difference disciplines (nursing, medicine, psychosocial/social justice) to better the patient's health. The model tends to be holistic and expanded through different points of care, so professionals are discussing the patient's health and future health where every aspect of care is part of the care plan. Interdisciplinary can also be an academic term when two areas of academic interest cross and fill a gap of knowledge. So, for instance, information technology and nursing would be nursing informatics. The higher education interdisciplinary is regarded simply as elective subjects taken from a variety of disciplines that in some way relate to a general topic. Here there are 'two or more disciplines [. . .] contributing their particular disciplinary knowledge on a common subject' (Garkovich 1982).

Moving further along the continuum of variants of interdisciplinary, at one extreme is a view of interdisciplinary as involving the 'collapse of academic borders and the emergence of a new discipline' (Davidson 2004). This is sometimes known as 'transdisciplinary' (MaxNeef 2005). However, dissolving academic boundaries would seem to go against the gains won in terms of the basic research productivity of individual disciplines. There are questions about how, in a practical sense, disciplines would continue work done in dedicated disciplinary areas of concern if boundaries were 'dissolved' and about how disciplinary integrity would be maintained. If boundaries between disciplines are dissolved, it becomes unclear to what extent traditional disciplines would survive, although some temporary boundary dissolution may lead to new disciplines (S. Marginson, personal communication, 27 April 2007). In the process of solving problems that are characterised by increased complexity, transdisciplinary can enlighten new points of view for the solutions and thus enhance creativity for innovations.

Methodology

The study was done by a literature review for the articles or reviews published between the years 2000 and 2016 within the higher education context. By the literature review methodology a general overview of the phenomenon can be achieved (Kothari 2004), as the published ar-

TABLE 1 Scopus Bibliographic Database Science Classification

Computer Science	General Computer Science, Computer Science (miscellaneous), Artificial Intelligence, Computational Theory and Mathematics, Computer Graphics and Computer-Aided Design, Computer Networks and Communications, Computer Science Applications, Computer Vision and Pattern Recognition, Hardware and Architecture, Human-Computer Interaction, Information Systems, Signal Processing, Software
Engineering	General Engineering, Engineering (miscellaneous), Aerospace Engineering, Automotive Engineering, Biomedical Engineering, Civil and Structural Engineering, Computational Mechanics, Control and Systems Engineering, Electrical and Electronic Engineering, Industrial and Manufacturing Engineering, Mechanical Engineering, Mechanics of Materials, Ocean Engineering, Safety, Risk, Reliability and Quality, Media Technology, Building and Construction, Architecture
Medicine	General Medicine, Medicine (miscellaneous), Anatomy, Anaesthesiology and Pain Medicine, Biochemistry, medical, Cardiology and Cardiovascular Medicine, Critical Care and Intensive Care Medicine, Complementary and alternative medicine, Dermatology, Drug guides, Embryology, Emergency Medicine, Endocrinology, Diabetes and Metabolism, Epidemiology, Family Practice, Gastroenterology, Genetics (clinical), Geriatrics and Gerontology, Health Informatics, Health Policy, Haematology, Herpetology, Histology, Immunology and Allergy, Internal Medicine, Infectious Diseases, Microbiology (medical), Nephrology, Clinical Neurology, Obstetrics and Gynaecology, Oncology, Ophthalmology, Orthopaedics and Sports Medicine, Otorhinolaryngology, Pathology and Forensic Medicine, Paediatrics, Perinatology, and Child Health, Pharmacology (medical), Physiology (medical), Psychiatry and Mental health, Public Health, Environmental and Occupational Health, Pulmonary and Respiratory Medicine, Radiology Nuclear Medicine and imaging, Rehabilitation, Reproductive Medicine, Reviews and References, Medical, Rheumatology, Surgery, Transplantation, Urology

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ticles and reviews are indicating the interest towards the subject from various topical angles. A search for the scientifically published articles or review papers was directed to Scopus, one of the biggest bibliographic databases having more than 69 million records today (see https://www.scopus.com). For gaining a result-set to be analysed altogether three individual searches with different keywords were performed. For this result-set the analysis was performed in two different parts to study each research question, RQ1 and RQ2, separately.

The searches were performed for the title, abstracts and keywords of the articles and reviews published between the years 2000 and 2016 by us-

TABLE 1 *Continued from the previous page*

Nursing	General Nursing, Nursing (miscellaneous), Advanced and Specialised Nursing, Assessment and Diagnosis, Care Planning, Community and Home Care, Critical Care, Emergency, Fundamentals and skills, Gerontology, Issues, ethics and legal aspects, Leadership and Management, LPN and LVN, Maternity and Midwifery, Medical-Surgical, Nurse Assisting, Nutrition and Dietetics, Oncology (nursing), Pathophysiology, Paediatrics, Pharmacology (nursing), Psychiatric Mental Health, Research and Theory, Review and Exam Preparation
Social Sciences	General Social Sciences, Social Sciences (miscellaneous), Archaeology, Development, Education, Geography, Planning and Development, Health(social science), Human Factors and Ergonomics, Law, Library and Information Sciences, Linguistics and Language, Safety Research, Sociology and Political Science, Transportation, Anthropology, Communication, Cultural Studies, Demography, Gender Studies, Life-span and Life-course Studies, Political Science and International Relations, Public Administration, Urban Studies

NOTES Adapted from https://www.scopus.com.

ing keywords. Keywords used were: 'interdisciplinary higher education,' 'multidisciplinary higher education' and 'interprofessional higher education.' The search produced the result-set of total amount of 6328 articles or reviews, which was analysed by the Scopus bibliographic database analysis tool (see https://www.scopus.com). The analysis tool provides information from the result-set broken down by year, source, author, affiliation, country, document type and subject area. In case of analysis for the RQ1, the result-set was analysed by the used keywords and publication year. For the analysis of the RQ2, the Scopus analysis tools Subject area classification was used. The classification identifies and categorises the published research into different disciplines and its sub-areas. In addition to the subject under this study, computer science and engineering, table 1 summarises the sub-areas of the three Subject areas; medicine, nursing, social sciences and engineering.

Results

The first research question of this paper, RQ1, focuses on the trends of higher education in regards to multidisciplinary and interdisciplinary education. Figure 1 illustrates four graphs as a summary of the first analysis. The graph 1 illustrates the amount of publications and articles or reviews published yearly between the years 2000 and 20016. The graph on the top is summarising the amount of articles and reviews published having 'in-

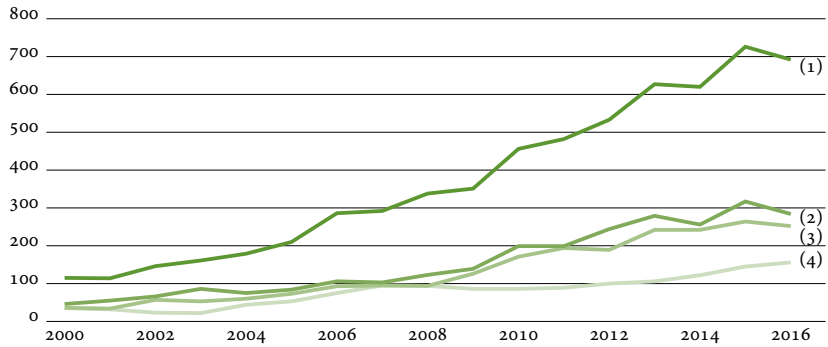

FIGURE 1 Publications in Scopus by Matching Keywords between the Years 2000–2016 (1 – total, 2 – interdisciplinary higher education, 3 – multidisciplinary higher education, 4 – interprofessional higher education)

terdisciplinary,' 'multidisciplinary' or 'interprofessional' and 'higher education' in their title, abstract or keywords.

The figure 1 shows that the total amount of articles has been growing steadily over time between the years 2000 and 2016. In year 2000 there was together 115 articles published, in year 2010 together 456 articles published and the highest amount of articles so far, 726, was published on year 2015. The growing number of yearly-published articles indicates the researchers' interest towards the importance of the role of interdisciplinary, multidisciplinary and interprofessional education.

Between the years 2000 and 2007 in the figure 1 the three lower graphs, interdisciplinary, multidisciplinary and interprofessional higher education, seem to grow on a similar pace. After the year 2007, the interprofessional education research seems to grow in a lower pace, even to decrease, compared to the other two that keep a similar pace all the way to year 2016. These two graphs, which illustrate the amount of articles published focusing either multidisciplinary or interdisciplinary higher education, are growing about the same rate, so there is no clear distinction that one of the topics would have been published more than the other. In year 2000 there were 35 articles published on interdisciplinary higher education while multidisciplinary higher education 46 articles published. In 2016 the former had 284 articles published while the latter had 252 published. This possibly indicates the interest towards interdisciplinary higher education research. The indication seems logical because the needs for boundary crossing competences and metaskills for knowledge workers might benefit more from interdisciplinary style of education.

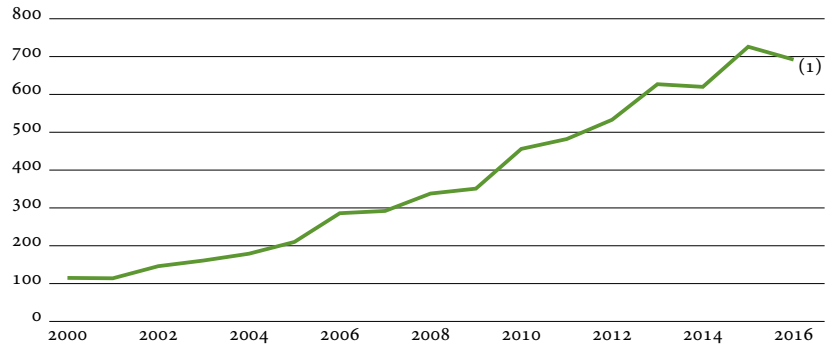

FIGURE 2 Publications in Scopus by the Subjects and Matching Keywords between the Years 2000–2016 (1 – all fields)

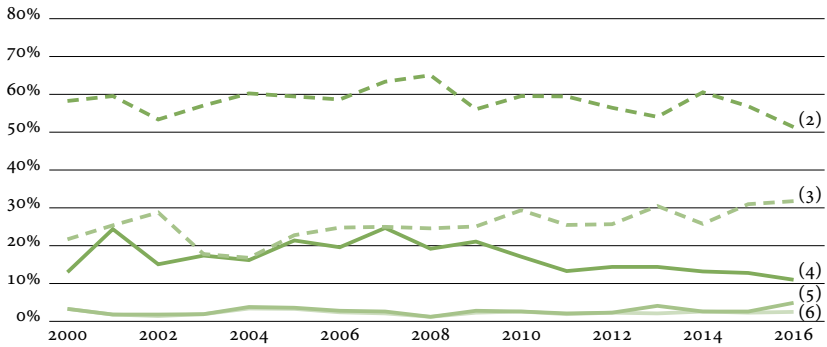

FIGURE 3 Publications in Scopus by the Subjects and Matching Keywords between the Years 2000–2016 (2 – medicine, 3 – social sciences, 4 – nursing, 5 – engineering, 6 – computer science)

The second research question, RQ2, focuses in which disciplines interdisciplinary, multidisciplinary and interprofessional higher education is utilised the most. In the study a more detailed analysis for the previously searched result-set was performed. Figures 2 and 3 illustrate six different graphs as a summary of the second analysis. The graph on the top is the same than in the figure 1, displaying the total number of articles or reviews in Scopus that match either 'interdisciplinary,' 'multidisciplinary' or 'interprofessional' and 'higher education' in their title, abstract or keywords.

The graphs in figures 2 and 3 illustrate the following subjects, their amount and relative share of the total articles or reviews published yearly between the years 2000 and 20016. The graph 1 (in figure 2) is the total number of published articles or reviews. In figure 3 the five graphs

illustrate how the relative share of published articles has changed over the years in selected fields. The second graph in figure 3 is medicine, the third graph is social sciences, the fourth graph is nursing, the fifth graph is engineering and the sixth is computer science. From the figures 2 and 3 it can be seen that the interest towards of interdisciplinary, multidisciplinary and interprofessional education is a growing trend on all of the studied disciplines except nursing. Traditionally the disciplines publishing the most have been the medicine and social sciences. The interdisciplinary, multidisciplinary and interprofessional higher education publications on medicine has maintained its popularity over the time, while the relative amount of social sciences publications has been increased steadily. Nevertheless, these two disciplines publish by far the most articles on multidisciplinary, interdisciplinary and interprofessional education. For example, from the graphs can be seen that in 2000 58.3% of all articles or reviews published where on medicine. In 2016 the share of all articles on medicine was 51.4%. So, even if the total number of articles or reviews on medicine has increased from 67 in 2000 to 356 in 2016, the relative share of publications is down only by 6.9%. The share of social sciences' publications has been growing steadily from 21.7% to 31.8%. This indicates that most likely importance of social sciences will remain high also in the future.

Third graph in figure 3 illustrates that nursing's publications amounts has stayed about the same from 2000 to 2016. However, the graph indicates the decreasing trend of relative publication rate, since between 2005 and 2009 the rate was around 20% and since 2010 closer to even 10%. The last two graphs illustrate the engineering and computer science publication amounts, thus indicating publication rates to remain relative low for most of the time period. Engineering publication rate has remained less than 3.5% for the most time period, as small growth has appeared within the last years. Computer sciences publication rate has imitated the somewhat similar path than engineering, staying less than 3.5% in the relative amount of publications. The difference between the engineering and computer science publication rate has been only during the year 2016, prior to that both of them the publication rate has grown almost identical.

Conclusion

In this article we studied the trend of multidisciplinary, interdisciplinary and interprofessional higher education. The study was focusing whether

this kind of teaching was gaining more attention in the 2000s, and, in addition, to know what fields of research were mostly taking the advantage of interdisciplinary, multidisciplinary and interprofessional teaching. The results indicate that the general research interest towards collaborative learning in higher education has been growing steadily between the years 2000 and 2016. Interdisciplinary, multidisciplinary and interprofessional ways of education have gained around the same amount of interest during the above-mentioned time frame. The yearly amount of research publications has grown from year 2000's 115 articles or reviews to around 700 in years 2015 and 2016. This result indicates that the researchers and educators have noted the importance of multidisciplinary, interdisciplinary and interprofessional higher education.

Based on the results there is a strong indication that interdisciplinary, multidisciplinary and interprofessional education is not as common among computer science and engineering higher education studies as it is in e.g. healthcare or social sciences. Looking more closely on the different subjects of research we can see that medicine, social sciences and nursing have stayed the most productive areas for publications. Out of these three the number of articles written in medicine and social sciences has increased steadily, while the number of published articles in nursing has not increased. In the field of computer science and engineering the relative amount of publications compared to other fields has remained steady but not significant.

Engineering and computer science seems to be the two fields where especially interdisciplinary and multidisciplinary education has room to grow. Because of digital disruption, the use of computing and ICT in general is expanding into new industry areas, the role of computer science will be increased in the solutions (e.g. services and products) development as well. Most study programmes overall could benefit from multidisciplinary or interdisciplinary teaching due to increasing need of computing, as well as digitised products and services. Thus, potentially the number of scientific articles in the field of computer science that focus especially on interdisciplinary and multidisciplinary education will increase in the future. In addition, since the authors of this article are from computer science and engineering, based on our experience teachers on these disciplines tend to more likely focus on content and less on pedagogy. Thus there's a great demand for interdisciplinary and multidisciplinary mind-set to grow in the computer science and engineering fields of education.

Potential limitation of this study is the correlation of published research papers and actual educational activities performed in higher education institutions. In other words, if there is an indication of increased research interest towards interdisciplinary and multidisciplinary education, does it also mean increased amount of education offered by such way? On the other hand, there can be interdisciplinary and multidisciplinary education programs that are not reported by academic publications. Nevertheless, according authors opinion this is true for all fields of study and it doesn't skew the results one way or the other. In addition, the study was focusing on search titles, keywords and abstracts from the articles and papers from Scopus bibliographic database. For this the authors trust that Scopus' classification of articles is correct and that the articles indexed in Scopus offer a good representation of all research performed in the area of interdisciplinary and multidisciplinary research on higher education.

Another possible limitation for this study is the Subjects classification provided by Scopus bibliographic database. From the table 1 it can be seen that the medicine has the most sub-areas under the Subjects classification. Potentially this could correlate to the total amount of publications in medicine, and effect to the study in number of articles published. Still the results regarding the relative amounts of publications between different studied subjects, shows a clear distinction between the most active (medicine, social sciences and nursing) and less active (computer science and engineering) subjects of publishers. In addition, the longer heritage of professional collaboration in health care probably affects to the amount of publications.

As a future research we propose to continue study towards more detailed analysis of the articles and reviews found. By analysing the abstracts of all computer science and engineering classified articles and reviews, the types of interdisciplinary, multidisciplinary or interprofessional teaching they offer can be studied. Also by studying the publications of the major universities and colleges, we propose to find the current state-of-the-art interdisciplinary and multidisciplinary education program curricula. We also propose to study if there are any special requirements that computer science or engineering poses for interdisciplinary and multidisciplinary education. Finally, we propose to replicate this study within couple of years to see whether the role of interdisciplinary, multidisciplinary and interprofessional research has increased especially in the field of computer science or engineering.

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