SDPS-2021
Printed in US, December 2021

INCLUDING PERVASIVENESS AND UBIQUITY INTO THE HE CURRICULUM: EXPERIENCE FROM THE USN

Radmila Juric, Karoline M McClenaghan
University of South-Eastern Norway
rju@usn.no karolinem@usn.no

ABSTRACT

Pervasive and ubiquitous environments, where the boundary between physical items and software artifacts are disappearing, have had a significant impact on education, because it is a double edge sward. Pervasiveness is interwoven in software tools and cyber physical spaces in which student learn and teachers disseminate knowledge, in collaborative and experiential manner. At the same time pervasive environments are computational spaces, created and managed by software. They should be a part of any HE curriculum as a teaching topic because they are not very different to any other software products. This paper looks at the possibilities of incorporating into 10 credit modules of the BSc program in Computer Engineering the understanding, characteristics, and evaluation of various examples of software ubiquity through explorative learning and a modest level of tutor intervention. The results confirmed that facilitating students learning by nourishing their individual interest in a variety of topics, which belong to pervasive computing, is the way forward and should be explored further.

INTRODUCTION

In December 2018, the IEEE Pervasive Computing Journal published an article on Pervasive Computing Education (Girouard, Kun, Rudaut & Shaer, 2013). Its story focuses on ubiquitous computing and Weiser's vision from 1991 (Weiser, 1991) in which "embedded networked devices become a part of the fabric of our lives". Considering that the computer science community took almost 10 years, after that Weiser's visionary paper to declare the pervasive computing to be a paradigm of the 21st century (Saha & Mukherjee, 2003), it is not a surprise that it took us almost 18 years since then to start talking extensively about Pervasive Computing education. The problem might be in various claims from different disciplines, that ubiquitous computing "belongs to them". Hardware/device manufacturers, electrical engineers, communication, sensory technologies specialists, computer scientists and software developers all claim that pervasive computing belongs to them.

In the last 10 years we started shifting our ubiquitous computing interests towards Internet of Things (IoT) as one of the best examples of pervasiveness where physical items, software artifacts and humans cohabit together (Mattern & Floerkemeier, 2010). The situation has not changed since 2010. There is no consensus on exactly what constitutes IoT (Bandyopadhyay & Sen, 2011) (Dorsemaine, Gaulier, Wary & Kheir, 2015) and to which discipline it belongs (Goumagias, Whalley, Dilaver & Cunningham, 2021). Therefore, Pervasive Computation education must address all these issues.

We do not deny that this is multidisciplinary field where even psychologists, social science and human computer interaction specialists have their say. This is true in real life, and it should be reflected in the Pervasive Computing education. However, there is one aspect of pervasive spaces, often neglected, which points directly towards computer science and computational models. Ubiquitous computing exists because we can create their instances, using computational models based on modelling abstractions, and deploying the models with available software technologies. Without such software solutions it would be difficult to imagine that we can have a functioning pervasive space (Shojanoori, 2013) (Shojanoori, Juric & Lohi, 2012) (Juric & Madland 2020). It is not enough to master physical connection, communications theories/practice, and understanding between hardware in pervasive spaces. We need deployed computational models to make ubiquity a reality.

Where do we go from here? What would be an essence of Pervasive Computing education?

The authors of (Girouard, Kun, Rudaut & Shaer, 2013) are clear in their thinking, that Pervasive Computing Education is related to teaching a multidisciplinary field with numerous applications, teaching students with diverse backgrounds, and not often supported with pedagogical underpinning in teaching relevant subjects. This means that there has been no active research on the role of teaching and learning practices in the field of Pervasive Computing and we have no verified ways of assessing if students are achieving learning outcomes, though the prescribed assessment. Bearing in mind that current students were born in the "ubiquitous world" and experience its pervasiveness since their childhood it is a very last moment that we re-think not only computer science education, but also our ability to teach across disciplines within defined academic programs.

This paper illustrates a specific way of addressing a wide spectrum of problem domains and software application in pervasive computing in Computer Engineering BSc Program, by looking at one subject on Data Management. The choice of subject was deliberate because data centric applications dominate current computing. We live in the world of data and information overload. The data determines the choice of computations. This is particularly true for algorithms which shape current vision of Artificial Intelligence (AI) and thus focusing on data management is a cradle for illustrating which aspects of pervasive computing are feasible to deliver.

In the next section, we describe the structure and novelties within the subject. In the section which follows, we touched on related work. In Conclusions, we outline lessons learned, look at the results plus raise questions on the suitability of our current educational structures in pushing teaching of Pervasive Computing to a different level.

DATA MANAGEMENT: A JOURNEY TOWARDS IOT, EDGE COMPUTING AND AI

The subject consists of two parts. The first part focuses on the traditional issues of data management within structure repositories such as relational databases. The second part focuses on explorative and research-based learning of the topics which take students towards Big Data Technologies, Semantic Web Technologies (SWT), IoT, Wearable and Edge Computing and AI.

PART 1: Traditional Database Management

This part of the subjects is equivalent of the 60% of the whole subject.

One of the learning outcomes in this subject is that the student should be able to plan, model, implement a database and present it in a web setting. Weekly lectures discussed theories on database modelling and normalization. It also included illustrations of connecting a database to webpages using PHP. Finally, the students could go through SQL, by looking at examples, and gradually making more complex queries. The recommended literature in Norwegian has been available for the students, if they wanted to have a physical book. However, they are recommended to avoid using the book and explore internet resources of their experiments.

At the start of the semester, students were given Assignment ONE relevant to the exam (30% of the total score). The task was to find an example of a database, designed through normalization plus use the rules for grouping the model into a database in 3rd normal form.

A practical assignment required to define a web application that uses a database – this can be the same database or another application. The students were encouraged to find an application of interest to them. It could range from traditional web shops, spa or wedding planners, and data bases about Games of Thrones / Diablo, to databases for scout groups, football clubs and information about fishing waters. The hand in for this assignment was a pdf report aimed at the "customer", explaining how (a) the database is constructed, and (b) the web application was created and maintain.

The implementation allowed students to choose whatever platform they want to learn, but we are clear that the second assignment on the exam (30%), will (i) give then a defined database (ii) ask them to write three SQL-queries, one with a join of multiple tables, one is a GROUP BY/HAVING and (iii) synchronize subquery. It was the students' responsibility to make sure they explore, learn and practice SQL to solve these tasks.

Throughout the semester, the students work on exam assignment one, discuss it with the lecturer and with each other and gradually get an understanding on how to build a database. They also program a database in connection with their web application, the chosen technologies, and successful experiments to improve their final product.

The outcome was interesting. Since the students were working on their own problem domain of interest, they put more effort into this web application and made sure that it was exactly what they would expect from it. They appeared to be more motivated than having the same set assignment across the class.

PART 2: Moving Towards Pervasive Computing

The second part of the subject is equivalent of the 40% of the whole subject.

It differed significantly from the first part, but it does continue from the essential knowledge on data management gained through the understanding of database systems.

This part of the subject had to change from year to year because of one important reason. Advances in software technologies from 2015 onwards, dependent on data centric computations changed drastically, almost beyond recognition. It moved from infrastructures developed at around 2010, known as Big Data technologies and uprise of IoT and Edge Computing to Algorithms for AI, which heavily depend on data. In other words, there is a clear pathway in the data management world from traditional database management towards data science. If we add to these advances the power of data available on the Internet and its web pages, we must not forget SWT and linking the data though new web languages based on first order logic for introducing logic inference, and thus enable the functioning of the Web.

Obviously, it is impossible to create a subject which can cover all the above. Therefore, subject adopted a solution which made the inclusion of pervasiveness in it feasible.

(1) The content of the subject was divided into min 14 sections which covered topics which would be of interest to students, but still important in data centric part of pervasive computing. The topics are: Big Data technologies and Hadoop ecosystem, The Power and Characteristics of Big Data, Not only SQL Databases, Web Data and RDF, SWT, Web data and languages, IoT: technologies, applications and challenges, Wearable Computing, Edge versus Cloud Computing, Predictive analytics and IBM Watson Studio, Evolution of AI, Finding triggers for making machine learning popular, exploring different examples of using ML models in various problem domain, Machine Learning versus AI.

(2) Formal lectures introduced the topics through discussions. The tutor listed academic sources of materials for reach topic, which help in understanding the importance and complexities of the topics.

(3) Students were divided into groups of not more than 7 and worked under tutor's guidelines. Each group could choose their own topic of interest from the list of topics and work on it through the rest of the semester.

(4) Student were encouraged to research individually and in groups to increase their reading lists and create an

academic output which will show the understanding of the subject and their learning curve.

(5) Presentations were organized to demonstrate learning and knowledge sharing across the class. This was one of the most important parts of the learning process. because of immediate feedback and opportunity to debate the topics publicly.

(6) The tutor had a facilitating role by checking and improving student reading list and answering questions students may have when facing difficult and not very well-known materials.

It was impossible to guess in advance which type of knowledge students would bring to presentations, because it depended on the choice of materials students read. Therefore, exam question should reflect the same. We had to create as many questions as possible a possible to cover materials student read and learned. This would mean that everyone could chose 2 out of at 20 question (in 2021) which would span all knowledge they demonstrated in presentations.

The outcome was very interesting.

Firstly, students' choices of topics of interest changed from year to year and moved from their interest in Big Data technologies and IoT towards Edge computing Machine learning and AI. Students were really following what was happening in reality and moving ahead with technologies and their advances.

Second, students discovered problematic issues in all these topics at the same time when they were learning about them. This was evident during question/answers sessions and in debates where disagreement and different views and opinions within group members were apparent.

Thirdly, the level of student confidence rose sharply when preparing them for the exam, because of their passion about the topic of interest and academic materials they read.

However, the formal assessment (exam) is far from the traditional. Presentations were based on pass/fail because an immediate feedback students get during presentations, is enough for continuing with learning. However, marking the answers in the exam was something different. The marks in the Exam cannot depend on the content of the given answers because students gained knowledge through reading various materials. In other words, student's answers depended on the type of the material they read. Therefore, marks are granted for creating an academic piece of work: a very short text, based on references, where students are allowed in not more than a couple of sentences to summarize their opinions (based on reading). One of the best outcomes was that no two answers across the cohort of 50 students were similar and only students who did not attend workshop either fail this part of subject or scored very low marks.

RELATED WORK

Publications on Pervasive Computing Education are sporadic and rare. Some of them could be found in IEEE Pervasive Computing Journal and ACM publications. Due to space restrictions we choose to comment on a couple of interesting papers which may have influenced this work.

The authors of (Janssen et al, 2020) illustrate the importance of interdisciplinary education while teaching "non-engineering" topics to students of engineering and other disciplines. It is interesting that they exercise their approach to the assessment like ours, but their motivation is rather different. They address the diversity of the classes in terms of student educational and cultural backgrounds and intention to create the environment highly relevant to practice and industry. This is understandable because their courses belong to the Artificial Intelligence program. However, they do not show how interdisciplinarity is covered in the content and materials and how they measured student learning, except balancing classes according to diversities.

In paper (He, Lo, Xie & Lartigue, 2016) we can read about integrating IoT into STEM education. Their case study is of technology infused courseware for embedded system course. They have very interested learning framework which secures learning approach and designing method of the IoT based learning framework. However, this paper is now signaling that we can use Pervasive computing for a different purpose in education. Therefore, it is important to emphasize that there are two distinctive ways of using pervasive computing in education (Hurson & Sedigh, 2009). It can be used as an instrument for creating a learning environment specifically designed for learning as exploited in (Viberg & Mavroudi et al, 2018). In these cases, pervasive space is "sitting in the background" and enables learning within it. However, we are interested in something completely opposite: how do we teach design of pervasive spaces and how do we proceed with creating conceptual models which will ensure their existence? Interesting thoughts can be found in (Mavroudi et al, 2019).

It is inevitable, that learning about ubiquity in computing in 2021 is rather complex and brings back again our old thoughts of computational thinking (Wing, 2006) as one of the most important skills in the 21st century (Denning et al., 2021).

CONCLUSIONS

This paper illustrates the ideas of introducing Pervasive Computing topics in the traditional Computer Engineering curriculum, within one subject which proved to be suitable for finding the ways of teaching students about the values and characteristics of pervasive computing. By placing our teaching within the data management subject, i.e., databases, we achieve both goals. Teaching the basic principles of database modeling and using this basic knowledge for exploiting topics relevant to data management across pervasive computing: from IoT, wearable and edge computing towards AI. Education communities, when creating curriculum, very often forget that the data management is the main backbone of any type of computing and the existence of pervasive space heavily depend on data (Shojanoori, 2013). Therefore, it is much easier to explain the characteristics of IoT, Edge computing and the computations with/within wearables if we have a clear understanding of what the role of data is in creating instances of pervasive spaces.

It is important to note, that Part 1 and Part 2 sections look rather different, particularly in terms of structure, considering that they belong to the same subject. This was done deliberately. It allows the freedom of moving between these parts, according to the possible changes in pervasive computing. It also shows that the core of understanding the basic principles of data management in Part 1 is sufficient to carry on with a plethora of problem domains in Part 2, because the data and its management does shape the current pervasive computing.

One of the best outcomes of delivering this subject is students' independence and their confidence in exploring and learning through research. The tutor role was more of a facilitator. Educators who like to adhere to a more traditional way of delivering similar subjects, might not like the fact that students had, in some parts of their formal examination, a freedom to give answers according to their individual reading, which eliminates model answers created by teachers as a criterion in marking. However, educators who strive for individuality and freedom of expression in learning, would find this example useful for achieving students' centered learning and addressing challenges of including pervasive computing in a HE curriculum.

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