DEVELOPMENT OF DESIGN COMPETENCES FOR INTERNATIONAL TEAM-BASED CYBER PHYSICAL SYSTEMS

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ABSTRACT

During the last decennia new product categories have been and are being developed, that have embedded real-time technologies for sensing and controlling the environment, using ambient technologies. These technologies are based on Ubiquitous Technologies (UT) and Cyber Physical Systems (CPS). Generally such systems include sensors, data transmitters, data processing units and actors. At the same time more traditional products often have been upgraded with intelligence incorporated. Our indoor and outdoor environment is becoming increasingly smart to enable providing services. In the same time we observe increasing globalisation and complexity of societal structures, communication, economy and politics [1]. Such developments affect the life settings of society and individuals. An important consequence is that coming industrial designers will therefore have an increasing responsibility for applying the new technologies and for taking care of ethical issues. Obviously Design Education Institutes (DEI) have to cope with such developments. This paper presents our findings how multi-x student teams can be prepared to investigate societal problems, how to develop the individual competences and feeling of responsibility towards such issues in their future professional life, to realise concrete artefacts that can contribute to solving such problems, and how to implement such finding in a concrete educational curriculum.

KEYWORDS

Design education, international collaboration, social design, ubiquitous technology, cyber physical system

1. INTRODUCTION

Everywhere around us technological intelligence and Ubiquitous Technologies (UT) appear in the form of smart systems and Cyber Physical Systems (CPS). New product categories, that are based on sensing, transmission, processing and activation are emerging on a global scale in the fields of medicine, agriculture, education, etc., while more traditional products often get intelligence incorporated [2]. We observed that the intelligence, incorporated in the environment is increasing. Specific services are provided such as way-finding or giving concrete information about local opportunities including shops, hospitals and museums. In addition communication is becoming more and more global, which is accompanied by increased complexity. We see the same happening with organisational structures in our society [1]. Also economics and politics are becoming more intricate. Issues such as Big Brother is watching you [3] and privacy are appearing in the public media more and more. Evidently such developments affect our life settings, not only for us as individuals, but also for society as a whole.

It is our opinion that coming designers will have an increasing responsibility for on the one hand applying the new technologies in products and environments while on the other hand they have to take care that ethical
issues will be assured. They have to enhance their soft skills so that they can develop their awareness, moral sensitivity, pro-activeness and social responsibility. Even more than in the past they must be emotionally reflective and able to envision the effect their artifact will have in society before it is out there.

It is evident that Design Education Institutes (DEI) have the task to prepare students for coping with such developments and for global cooperation in the professional design scene [4]. We see that the context of such cooperation, for designers as well as for experts, is becoming increasingly virtual (based on digital means of communication), multi-national and multi-disciplinary (we coined the expression multi-x). Nevertheless the current educational curricula of DEI seem to lag behind in following such developments and do not offer sufficient support for multi-x collaboration.

As design education staff we recognised such developments several years ago, and started building up some first experience, knowledge and skills in the area of multi-x cooperation, in European context (2000-2008) and in world-wide context [5].

This paper presents (i) a brief impression of current trends and developments and their consequences on society, (ii) our vision how design students can be prepared for a future with CPS, (iii) an implementation of this vision in a concrete masters course and (iv) an evaluation of the results.

1.1. Emerging society

The history of the human species can be seen as a multi-dimensional development of individual and social awareness, norms and behaviour, arts, technique and science, which becomes manifest in the characteristics of individual and social life, of the environment and artifacts, see figure 1. In social life we see the influences of trends and developments such as artefact’s for communication, cooperation and competitiveness. In the last decades the development of UT resulted in numerous CPS. In the areas of communication and cooperation increasing use is made of technological means (letters, phone, email, video-conferencing). Such developments have become manifest in the globalisation of industry, production, communication, education, travelling, etc. Biometrics studies have resulted in numerous applications such as personal identification, using fingerprint identification techniques, iris recognition, face recognition, speaker recognition, etc. [6, 7].

Where CPS function to provide environmental awareness, opportunities exist for beneficial and useful applications for personal settings [8], as well as for the area of e.g., arts. On the environmental level the arising of CPS has given the possibilities for a reduction of environmental pollution (for instance: email resulted in less paper communication and video conferencing technologies in reduced need for travelling). In the contexts of education (design and technique) and entrepreneurship the increased awareness and individual responsibilities have emphasised the focus on sustainability. As a consequence politics and economics are following such trends and developments and are adapting legislation to be in tune with such trends.

1.2. Indicators in society

Such developments imply that society has become severely dependent on technologies. Since much use is made of knowledge in the cloud that is increasingly uncontrollable (although governmental institutions pretend safety), humans, particularly designers, have a new responsibility when designing (for) this knowledge and when using this knowledge. At the same time serious privacy issues have arisen for individuals and for society [9]. The effect of dehumanisation has been introduced to indicate higher priority of the State over the interests of individuals (in favour of “the general interest”) and thus destroy personal freedom and civil rights [6].

The technological and organisational developments and their manifestations have resulted in many applications and as a consequence in specific indicators in our societies. In this section we will briefly discuss these indicators from the point of view of individuals, society and environment.

On the individual level interactions with a smart environment have been realised, such as outdoor (e.g., route planners) and indoor orientation, and possibilities for adaptation of artefact’s and work spaces to personal preferences [10, 11]. These innovations enabled a new way of ergonomic consideration for individual adaptation of artefact’s and environments. We are aware of the debate if smart systems do contribute to making us more dumb by controlling our personal life settings. It is about the difference between having our parameters of life embedded and automated, versus taking decisions personally and having individually conscious control of the interaction with our environment. We think that designers should be equipped with the competences to handle such considerations in an ethically correct way.

On societal level the concept of ubiquity has been
rooted firmly. Being able to communicate with anyone worldwide as well as to find knowledge and information in the cloud has become a common option. We see that many organisations, governmental and commercial, are being transformed for increased transparency (as long as dehumanisation is not a goal) and new concepts for retail. Another effect is an increased awareness and feeling of responsibility for people suffering anywhere in the world.

1.3. The position of the designer in this emerging society

In relation to the idea of a controllable society the coming designer has to find his position in applying of UT, CPS and biometrics for political, diplomatic and organisational purposes. The following questions deserve attention of the DEI all around the world.

- What are the new responsibilities of the coming designers?
- What problems do they have to cope with?
- How should a designer act in the new world?
- What new or extended competences are required compared to the current situation?

With this exploding field of UT and CPS society needs designers that have knowledge of (i) the new technologies, the possibilities to apply them and the new visions on product life cycle, (ii) the mental, cognitive and emotional aspects of humans, (iii) cultures and sociology, (iv) ethics, (v) national and international legislation and (vi) aspects of a controllable society. They have to be aware of the consequences of possible mentally orthotic functionalities of the new artifact service systems for the quality of life and the development of human capacities such as cognition, memory, emotions and reasoning. In addition we might consider the increasing dependency on artifacts and the risk of underdeveloping our human capacities.

1.4. Vision on education

According to our experience the current design educational programs [12] do contribute only slightly and in a fragmented way to the development of design competence for coping with the emerging society as mentioned in this paper.

How can we offer an academic course to our academic students so that they will be sufficiently equipped to
cope with the new context and to learn about their possibilities and responsibilities towards society as designers? We splitted this problem in two questions.

- What are the implications for implementing such aspects in a design educational curriculum? This will be further discussed in section 2 on the emerging requirements.
- How can it be achieved? This will be discussed in section 3.

2. REQUIREMENTS FOR NEW DESIGN EDUCATION

Based on our experiences with the former European Global Product Realisation courses and information from the literature [13, 14, 15, 16] Horváth et al. assumed that the combination of five basic capacities including design capabilities, knowledge, attitude, skills and experience jointly provide the resources for design competence [5]. Figure 2 gives a few examples of the contents of these capacities that have been defined and detailed in [4]. These five capacities should be developed in balance in educational design programs.

In order to approach the mentioned design competences, we envision that issues such as social responsibility, advanced communication facilities, multi-x educational environment, cooperation awareness, and other competences such as international intellectual property are relevant for DEI to include in their curriculum.

The context for this education is an international web where information is no longer a privilege among the wealthiest or smartest. Hence DEI should offer a different added value focusing on the content and the educational experience.

Participating in an international design team, is an excellent design educational experience. Besides, design teams are of major importance in any organizational context because groups of individuals work together in order to accomplish problems they cannot solve on their own [17].

2.1. Awareness of new responsibilities

As part of a society, designers must be responsible of the products and services that they design along its whole life cycle.

A first awareness that designers within a multi-x cooperation team must be instructed is global issues. Problems to be solved in a certain country may be already solved in another, especially when the countries or cities belong to different economic worlds, as it is the case for the Ubiquitous Product and Service Innovation (UPSI) course. In this way any DEI should give awareness about the requirements around the globe and not only locally, which in turn could ease the first question that teams must deal with: What societal problem to solve? In this sense the design issues discussed during UPSI 2013-1, as will be further mentioned, were related with global issues [18] such as food, sustainable development, and health issues.

A second awareness that designers must be taught of is the under development of human capacities, mentioned in section 1.3, designers must seek a balance and think about how to avoid spoiling the users with their products when not used properly. This could lead into an interesting new design field within the Design for X trends, and that is Design for Humanization.

A third awareness is ethics. A current service example shows that while we use technology to communicate, companies offering such services have different interests and are spying people’s information for politic and merchandising applications such as the recent Prism Surveillance System scandal [19]. A current product example shows that studies of the brain would represent significant advances for the neurological society, but it could lead into developments such as Brain Computer Interfaces (BCI) which represent a good example of a CPS but could easily invade people’s most valuable asset: personality. In both cases the ethics behind a service or a product requires special surveillance.
2.2. Advanced communication

Communication among humans is a complicated task, and in a multi-x international context it could make this experience quite frustrating when not performed correctly. Communication involves at least two entities, where body language, vocabulary, slang, language, timing and punctuality play a significant role.

In this way DEI should make a special effort in communication facilities. In first hand to reach most of the senses during the remote meetings, and in second hand, to be as effective as possible because the time window could be very small as it will be discussed in section 6.1 and meetings could last up to 7 hours (as experienced by Team A which is further mentioned in section 5.2).

Nowadays many solutions are commercially available that could lead into audible, visual, text or combined based meetings, but with different cost/benefit ratios. For instance the time effort required to type/write ideas correctly while chatting or emailing is higher than through audio, while in the other hand the time elapsed to reach an audio communication could be higher than just sending a text message. Thus deciding upon which tool to use and what for is another education requirement in the context of multi-x cooperation, with a special component of awareness for body language.

As a first attempt to address this question table 1 shows a comparison of different ways to have a remote meeting in reference with a face to face communication, according to the following variables:

- Speed to effectively send a short message
- Time that the meeting could last before becoming inefficient
- Awareness of body language so that members can sense each others feelings
- Number of participants that can actively take part within a remote meeting
- Capability to share sketches and technical design details
- Technical requirements to fulfill remote communication

Since people need to communicate in any context, and not only during education, they develop skills in a daily rhythm as technology brings solutions. Nevertheless DEI should not take this fact for granted, specially when different laws rule according to each country.

Finally, members should communicate not only between them but with the CPS being designed. By means of software, there are many collaborative tools, while by means of hardware, remote engineering is one of the future directions for advanced teleworking/e-working [20] and designers will eventually require to deal with it.

2.3. Co-operation

Cooperation is a relative word. According to our experiences some countries are more into leading the process, while others are more into being told what to do, and both reflect cooperation. As a matter of fact, the average attitude of the participants is related with the country’s context, namely economically and politically.

In practice, prior to the workshop UPSI 2013-1 which took place in Wuhan, People’s Republic of China (PRC), the Colombian students and coaches took part on a Chinese culture course given by Confucius Institute which was helpful to understand how to interact in several situations. Therefore each participant institution should lecture the cultural aspects that are going to play a significant role within the multi-x experience. Thus another educational requirement is to contextualize the students with the cultures that are participating.

Consequently, from the very beginning of the course becomes important to establish a group hierarchy in order that each participant knows the role that he/she is going to play. Individuals must take part not only in the design task but structuring and organizing the group process [17].

2.4. Multi-X

Within our research area, the educational means for CPS teaching require hardware and software to ease each of the design processes (further discussed in section 4.1).

Technically, a CPS is a mechatronic system (figure 3(a)), and any educational framework has to facilitate the access for physical components to design and develop a CPS.

Additionally, mechatronic systems require knowledge of different areas such as mechanics, electrics, electronics and informatics (figure 3(b)), therefore good skills for each of these areas are required among a CPS development team. And as depicted in table 4, the disciplines of the participants had to be diverse. As a requirement, designers must understand what is the role of the others and what are they capable to do, instead of trying to manage everything by themselves, which is usually misunderstood among the mecha-
Means & Time of Body Number of Design Technical

<table>
<thead>
<tr>
<th>Means</th>
<th>Speed</th>
<th>Time of Meeting</th>
<th>Body Language</th>
<th>Number of Participants</th>
<th>Design Details</th>
<th>Technical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face to Face</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓✓</td>
<td>✓</td>
<td>✓✓</td>
<td>✓</td>
</tr>
<tr>
<td>Text</td>
<td>✓✓</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>✓✓</td>
<td>✓</td>
</tr>
<tr>
<td>Audio</td>
<td>xx</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>Video</td>
<td>xx</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Text &amp; Audio</td>
<td>✓✓</td>
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</tr>
<tr>
<td>Text &amp; Video</td>
<td>x</td>
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<td>✓</td>
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<td>✓</td>
</tr>
</tbody>
</table>

Table 1 Communication means comparison (✓✓=Very good, ✓=Good, -=Normal, x=Bad, xx=Very bad).

2.5. Extended competences

Another requirement for design education is to transfer Intellectual Property (IP) tools, specially when each participating country may have different IP legislation. Documents such as a Non Disclosure Agreement and a contract with its respective IP paragraphs should be signed before starting a multi-x cooperation project, in order that all the parties are redundantly clear about how is the IP going to be distributed in the event that a patent, industrial design or any other IP result shows up.

Special care must be taken in a world context where innovation is considered as a development indicator, while in the other hand it share information without limits. In this path, technology surveillance plays a significant role and it should be considered as design competence. Therefore patent search, International Patent Classification (IPC) and claims should no longer be a matter only for lawyers but designers as well.

2.6. Requirements summary

The previously discussed requirements would support the design competences (figure 2) for the coming CPS designers in the following way:

- **Capability** - awareness of mechatronic attributes
- **Attitude** - ethics and design for humanization
- **Knowledge** - global issues and global cultures
- **Skills** - technology skills and awareness of its functionality
- **Experience** - international intellectual property

A set-up of the educational system to approach these requirements and competences is discussed in the next section.

3. BASIC SET-UP-OF THE EDUCATIONAL SYSTEM

In order to move towards a new educational system that is able to cover the emerging requirements for future designers, the proposed educational system is characterised by certain attributes. To ensure the development of the aforementioned design requirements (section 2.6), while aligning to the envisioned competences 2, the course was planned so that students participating in it could familiarise themselves with the following:
Following a certain work flow to the development of CPS
Coping with the increased complexity that is introduced by (i) the new world, and (ii) the application of UT
Cooperating in teams under complicated conditions and limitations

3.1. The design process

The course is based on 5 different modules that will be able to support their work flow, all of which is culminated at the end of the course with students presenting their projects in a symposium:

- **Module 1** - Tracking down a societal problem and deepen understanding in that area by conducting social and technological research;
- **Module 2** - Conceptualising in multi-x context;
- **Module 3** - Creating together an abstract prototype;
- **Module 4** - Designing in detail (embodiment); and
- **Module 5** - Prototyping, verification and validation of the results.

Each module is supported by lectures given by all the universities, related from CPS to technical knowledge or even global issues (such intellectual property and dehumanisation), their current areas of application, their importance and meaning for the society and the technological advances to occur. The process and methods that would be used do not deviate much from the typical cycle of design (analysis-synthesis-simulation-evaluation) [22] but it did differ in certain aspects.

**Module 1**

The assignment of the course for the students would start, not by posing a specific problem area that could be quantified or engineered in numbers but by using the sensitivity and curiosity of the students to discover potential areas to work on enhancing their ability to think in a non one-to-one function-solution design strategy.

**Module 2**

Working in a multi-x context is know to increase the effectiveness and appropriateness of proposed design solutions along with innovation chances because of the diversity and the social interactions in the team [23]. Consequently conceptualising within such a team is expected to enhance the student’s capabilities that relate to their imagination and creativity.

**Module 3**

The development of an abstract prototype as described in [24] is on its own a framework that can offer quality improvement for the proposed solution amongst over strengths. Using it within the specific context we aim at the students to use their imagination and envisioning skills for the effect (positive or negative) their product will have on the society allowing the value of their design to emerge and become apparent. It is a way to create the vision and share it to companies that can support it further to the society on a very early stage of development.

**Module 4**

This phase is perhaps the most demanding one, as it requires expertise on the behalf of each individual, collaboration and effective task distribution within the team. This is the part that will determine the quality of the final result and aims at developing the very core of the students, their knowledge and skills (see figure 2).

**Module 5**

This final phase will sharpen the collaboration and communication skills of the students as the team will come together in a workshop to finalise the course. In order for that to happen a lot of planning is required in advance so that the prototype is feasible in one week, as the workshop lasts.

3.2. The role of CPS in designing

The focus on CPS is expected to set a different, more open, mindset that render the students able to think in a different way compared to designing any other product. The nature of CPS is on its own so much broader than dealing with designing a product. A holistic approach needs to be adopted for all the elements to fit to the puzzle. The students, getting acquainted with the notion of CPS, will realise on their own the complexity of the needed design intervention along with the responsibilities that they will carry with the introduction of that solution to the public.

3.3. Team working

Collaboration is estimated to be the most difficult element for the students, given the circumstances, but also it is the element that will be the main source of inspiration and out-of-the-box thinking as students will explore not only different cultures but also different areas of expertise and ways of working. Students will have to manage their progress and agree on a way of get-
ting things done by distributing and defining the tasks within the team. They will be supervised but they will have to carry out shared responsibilities discovering the weaknesses and strengths of their teammates along with their own.

4. REALISATION

The most recently completed UPSI offering is the third implementation of a multi-x masters-level course aimed at preparing design students and has its beginnings in the Global Product Realisation (GPR) course that was offered by the Technical University of Delft (TU Delft) based in Delft, the Netherlands. Due to the multi-x nature of the course, several factors and aspects had to be considered and accommodated for in order to ensure the success that was achieved. Several of the more salient points are discussed in the subsections below.

4.1. Preparation

As part of the initial preparation, TU Delft identified and approached a number of universities that could offer the different aspects required to realise the multi-x nature of such a course. Ultimately, three institutions from widely geographically-dispersed locations across the globe were confirmed as collaborators - (i) Huazhong University of Science & Technology (HUST) in Wuhan, PRC; (ii) Universidad Escuela de Administración y Finanzas e Instituto Tecnológico (EAFIT) in Medellín, Colombia; and (iii) University of Johannesburg (UJ) in Johannesburg, South Africa.

Preparation meetings took place as early as three months prior to the commencement of the course in order to work out details of the course which included topics such as:

- Anticipated student numbers from each participating university and the disciplines of these students;
- Nominating staff members to serve as coaches for the various teams and their responsibilities;
- Scheduling the course with regard to time, content and weekly meetings;
- Streamlining lectured content;
- Testing video-conferencing facilities;
- Agreeing on final workshop location to realise physical implementation of solutions;
- Expected deliverables from teams during each week and each module;
- Identifying and securing appropriate presenters for the various lectures given the schedule; and
- Composing the teams so as to ensure multi-x team configurations (and thus maintain balance in quantity and skill) - table 2 shows the team compositions for UPSI 2013-1.

<table>
<thead>
<tr>
<th>Team</th>
<th>TU Delft</th>
<th>UJ</th>
<th>EAFIT</th>
<th>HUST</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>5</td>
<td>12</td>
<td>6</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 2 Number of members per team during UPSI 2013-1.

4.2. Academic schedule harmonisation

As maximum participation from all stakeholders involved is pivotal to the success of the course, arriving at a course schedule which would agree with the existing academic schedules of the four universities was very important. It soon became apparent upon correlating the schedules of the participant universities that establishing a schedule corresponding to all four academic calendars would not be possible, the two main reasons being:

- **Academic terms** - both Colombia and South Africa’s academic year start in January whereas September marks the beginning of a new one in China and the Netherlands. Recruiting sufficient student numbers is therefore a challenge for participating universities for whom semesters have already gone underway, particularly as students are less likely to agree to sign up for a course midway through a semester.

- **Public holidays** - different timing of holidays for the four universities existed - HUST, for example, had an extended holiday period during their Chinese new year in February while the other three universities would break away during the Easter period around April.

As a result, the only viable solution was to attempt to maximise optimal attendance. Where it was not possible, it was proposed that absent students demonstrate professionalism in their work ethic - those who are on holiday would do whatever is necessary to ensure that their team’s deliverables are completed, even if it meant that they had to put aside some of their vacation time in order to contribute to their team project.

Achieving this level of commitment from students was not always possible, with levels of co-operation in this regard varying from team to team. Reasons for being
unable to contribute included a lack of access to communication facilities and a lack of time due to other engagements.

4.3. Video-conferencing

Given that regular meetings, lectures and presentations had to be attended on a regular and frequent basis, the availability of video-conferencing facilities was essential for each of the participating universities. Part of the preparation included facilities being tested beforehand to identify and resolve any technical issues that existed. Test connection sessions were arranged in order to establish how the four participating universities would connect to each other and whether existing hardware was suitable for the format of video-conferencing sessions ahead. While TU Delft and EAFIT both had video-conferencing rooms, HUST and UJ had to rely on software-based solutions in this regard. A combination of factors, such as geographic location, Internet connection speeds, institutional information security policies, compatibility with the protocols of TU Delft and EAFIT’s systems, changing service conditions from service providers, hardware limitations, and licensing costs had to be considered in the evaluation of each possible solution.

As a result, much collaboration also took place amongst staff responsible for the technical support aspects of the course, with suggested solutions and configurations being exchanged regularly over the course of UPSI.

Results at the conclusion of the latest UPSI course have not produced a single clear solution as software-based video-conferencing solutions have been temporarily successful at best. On one occasion, a software solution that had proven to work for the twenty days prior suddenly rerouted all connections to an unknown conference facility in France. Technical support from the software provider remain unable to explain the phenomenon at the time of writing. Further research and testing is therefore warranted in order to identify reliable software-based video-conferencing solutions in the absence of physical video-conferencing facilities.

It should however also be noted that EAFIT and TU Delft participants had to schedule meetings carefully so as to ensure that they did have access to the video-conferencing facilities since the resource is shared with other members of their respective universities.

Overall, it was good practice to have secondary means of communicating with the other participants on hand at each meeting. Popular solutions include Skype™, WhatsApp™ and e-mail, allowing participants who had trouble connecting to stay in contact with the other parties in real-time.

5. RESULTS

In order to demonstrate having developed the necessary competencies to meet the requirements for new design education as identified and discussed in section 2, each of the four student teams in the latest UPSI course were required to produce a detailed report at the end of each of the five modules outlined in section 3.1. Additionally, teams were required to present a summary of their findings and results before an audience comprising their peers, coaches and other interested stakeholders, with feedback provided being considered as guidance for future aspects in subsequent modules. The end result is the culmination of the design and development of four CPSs aimed at addressing social needs as identified by the teams. The following subsections describe not only the outputs produced by each of the four teams at the end of each module, but also provide insight into how the UPSI course evolved through the various offerings to satisfy the changing landscape of design education.

5.1. UPSI 2011-2013: Development

Since its inception in 2011, the UPSI course has been continually developed on so that each iteration of the offering is improved in terms of value to students, thus allowing teams to produce work of high calibre. Not only does the course benefit from the lessons learnt during previous offerings of the UPSI course, but also from experiences obtained during UPSI’s predecessor GPR course.

Given the extensive time investment (regarded as being higher than regular courses) required from both students and coaches [25], one aspect of the course that underwent review was the scheduling of lectured content, resulting in the lecturing schedule of UPSI 2013-1 being streamlined. The move ensured that lectures presented were more relevant and useful while freeing up more time for the students to carry out the actual research, design and development of their team’s project.

5.2. Societal research

The end of the first module required that each of the four teams introduce their team identity in addition to summarising findings on various societal problems, focusing on a specific issue that could potentially benefit from the application of UT. It should be noted that
while students may not necessarily be required to develop completely new solutions, part of their research requires that investigations be carried out to determine what existing systems are already in place in order to introduce innovation to the existing market.

Team A, World Ubiquitous Project (WUP), elected to delve further into health care to focus specifically on tackling the problem of malnutrition in children, arguing that poor design and execution in existing solutions have not been as effective in producing better-informed parents and healthier children. WUP proposed that by applying UT, a novel solution could be produced to do away with unwieldy nutritional information systems that simply did not get used.

After reviewing common interests amongst the members, Team B decided on the name Domohhealth. Preliminary research revealed how medical attention required by the elderly may not always be met, particularly in light of an ageing population across the globe. Supported by preliminary research in home automation, the team suggested a solution to grant the elderly independence while obtaining medical assistance when necessary.

Team C’s Analog Circus focused on addressing the issue of reducing one’s environmental footprint at home. Believing that sustainability can be better achieved by engaging users in a more social manner, a smart home required by the elderly may not always be met, particularly in light of an ageing population across the globe. With the non-intrusive nature of ubiquitous technologies in mind, Ubicurious proposed a smart system that would accurately identify and warn drowsy drivers to take a rest before continuing their journey.

5.3. Conceptualisation of solutions

Having refined their problems in the previous module, each of the teams explored a number of available technologies, the application(s) of which could potentially address the various requirements of the problem domain. Each team also researched limitations of the various technological solutions proposed to determine their feasibility and integration with other technologies to form the final solution. For example, Team B investigated how best to distribute the various components needed for integration into a normal walking stick without the end product becoming cumbersome for use.

5.4. Abstract prototypes

For the purpose of producing an abstract prototype, all four teams elected to present the scenarios in which their proposed solutions would operate by means of videos. Each told a story which not only provided viewers with an explanation of the problem, but also described how the product would be deployed successfully. The abstract prototypes also revealed the insight of the various teams in envisioning how the various technologies identified in the previous module could be put together to achieve the conceptualised solution.

5.5. Developed products

To address the problem of poor nutrition habits in children, Team A proposed tasking children with feeding Foodamon, a virtual pet residing on a portable device such as a watch-like bracelet. Feeding is achieved when the child uses their device to scan the bar codes of food products that they are interested in buying. Based on the information that is linked to the bar code scanned, the behaviour of the virtual pet would change - food considered good makes the pet happy whereas repeatedly feeding it unhealthy foods will make the pet sad or angry. Such an approach intended to make learning about various food products interactive, setting nutritional goals for children.

To provide elderly people with the ability to live independently while providing their loved ones with peace of mind, Team B developed a walking stick called Smart Stick aimed at reducing the number of accidental spills that the elderly could take due to hazards or obstructions in their path. In addition to providing visual and audible alarms, the Smart Stick also alerted loved ones or medical help of possible incidences where the elderly user may have fallen and injured themselves, thus requiring medical attention.

With a non-intrusive, easy-to-install solution in mind, Team C came up with Smart Socket, taking a social-network approach to encouraging household owners to be more eco-conscious. A household’s power consumption would be monitored by socket devices sending this data back to a centralised reporting system. The reporting feature is intended to foster a competitive spirit amongst households to see who has been the most successful at saving the world.

As a means of reducing the number of accidents caused by drowsy drivers, Team D developed Mercury, a system aimed at monitoring a driver in terms of his heart-rate and driving behaviour to determine signs of drowsiness. Depending on the determined level of
drowsiness that was detected, the system would alert the driver, either through visual, audio or tactile warnings.

5.6. Presentations

In addition to presenting an introduction to their designs the four teams were required to demonstrate their physical systems to an open audience that comprised representatives from various industries in Wuhan as well as HUST academics and students. Feedback was particularly positive, with numerous interested parties asking when the final products would be available on the market and for the teams’ contact details for further research opportunities. The rest of the subsection provides a brief overview of the setup of the teams’ final presentations at the workshop.

To demonstrate their project, the members of Team A set up a shelf with boxes depicting various food products. Each box contained a bar code which could be scanned by the Foodamon device. Visitors testing the device would then see whether the food product they have just scanned was healthy or not.

Guests visiting Team B’s demonstration of their Smart Stick were given performances in which various members of the team took turns to act out the role of the elderly user who would navigate the area littered with obstacles. As part of the presentation, members also showed how the Smart Stick sent out a distress call to the relevant stakeholders should the elderly user fall.

To reproduce a house environment Team C created a floor-plan with a number of LEDs and sensors to provide a two-dimensional view of a household using the Smart Socket system. Visitors could then interact with the “house”, turning devices on and off and triggering sensors in order to simulate the house’s electricity consumption, readings which would be recorded and reflected on the Smart Socket mobile app.

In the absence of a vehicle environment in which Mercury would detect the various signs of a driver falling asleep, Team D welded a structure comprising a dashboard, steering wheel, rear-view mirror, and two cameras. The event of having the “vehicle” changing lanes was reproduced by moving a cardboard with a line to represent the road surface. Visitors were then invited to sit in the driver’s seat and act out various states of drowsiness.

6. DISCUSSION

6.1. Time zones

Initiatives such as UPSI are highly enriched by ideally having participants from the six continents, out of which four were represented during 2013 spring course by TUDelft (Europe), EAFIT (America), UJ (Africa) and HUST (Asia). Nevertheless it also shortens the time window (TW) for lecturing, coaching and co-working. Thus, in order to find a suitable TW with a time length for lectures $T_l$ of 2 hours, the analysis shown in table 3 was required.

6.2. Local sub-team building

Building teams at the beginning of the course was a task for the coaches. An effort was made to keep a balance in quantity and skill in order for the results to be as even as possible. Despite of it, a lack of students from some of the participating DEI was evident and became a difficulty for the development of the course (table 2).

While UPSI is intended to be a credit-bearing masters-level course, the approach undertaken by each of the participating universities has differed in this regard. The number, level and discipline of the students from each of the universities therefore varied as a result. For example, UJ students undertook the course purely for enrichment purposes whereas students from EAFIT and TUDelft were graded on their deliverables at the end of each module.

From a technical point of view, a CPS development team must include (see section 2.4) participants with skills at informatics, mechanics, electronics and electrics. Tables 4 and 5 on page 12 provide summaries of the approaches used by each university with regard to the students enrolled in the course.

6.3. Different perspectives of the course for the participating universities

From a Colombian perspective, in this case from Universidad EAFIT’s staff members, this course is a matter of allowing students to interact with different economic worlds. When they experiment being involved with team members from around the globe during their educational stage, it may become eventually trivial to interact with colleagues abroad once they reach the industry. Secondly this course becomes an opportunity for students to meet people from complementary areas and from different places (multi-x), which may lead to job opportunities as well as entrepreneur adventures.
Table 3  Time zone analysis (* time reference, ★ latest journey beginning time, ✩ earliest journey ending time).

<table>
<thead>
<tr>
<th>University (Country)</th>
<th>Credit</th>
<th>Level(s)</th>
<th>Discipline(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUST (China)</td>
<td>No</td>
<td>Postgraduates</td>
<td>Industrial design, Industrial engineers, Mechanical Design &amp; Manufacturing Automation</td>
</tr>
<tr>
<td>EAFIT (Colombia)</td>
<td>Yes</td>
<td>Masters &amp; Undergrads</td>
<td>Product design engineers, Mechanical engineers, Mechatronics engineers</td>
</tr>
<tr>
<td>TUDelft (Netherlands)</td>
<td>Yes</td>
<td>Masters</td>
<td>Industrial Design &amp; Engineering</td>
</tr>
<tr>
<td>UJ (South Africa)</td>
<td>No</td>
<td>Masters &amp; Honours</td>
<td>Computer Science</td>
</tr>
</tbody>
</table>

Table 4  Approaches of participating universities with regard to students (Part 1).

<table>
<thead>
<tr>
<th>University (Country)</th>
<th>Recruitment Process</th>
<th>Workshop Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>HUST (China)</td>
<td>Masters-level students were recruited by their professors</td>
<td>Each team given budget for purchasing required materials, services</td>
</tr>
<tr>
<td>EAFIT (Colombia)</td>
<td>Final project (compulsory deliverable) for undergraduate students; also offered to Masters students tutored by staff associated to UPSI course</td>
<td>Majority of students primarily funded by EAFIT</td>
</tr>
<tr>
<td>TUDelft (Netherlands)</td>
<td>Course was advertised on campus to qualifying students</td>
<td>Students expected to secure own funding</td>
</tr>
<tr>
<td>UJ (South Africa)</td>
<td>Potential students identified by South African staff and approached with opportunity to take part</td>
<td>Funding fully provided by the Academy of Computer Science &amp; Software Engineering</td>
</tr>
</tbody>
</table>

Table 5  Approaches of participating universities with regard to students (Part 2).
For the Delft students this course is one of the possibilities to do the last design exercise before graduation. The basic idea is that the three master educations (strategic product design, design for interaction and integral product design) work together in one project connected to a company assignment. Therefore this course is coined Joint Masters project. In the UPSI course they have a chance to add multi-x to the characteristics of the course.

The value in exposing students to a global experience is also strongly advocated by UJ’s academic staff as students in the field of Computer Science are expected to be able to collaborate and compete comfortably at an international and cross-disciplinary level. Furthermore, there is concern that students sheltered within a single environment are prone to “academic inbreeding” - the opportunity to work with students from other environments thus not only broadens the views of the students, but new skill sets beyond the domain of Information Technology are acquired.

Finally, for institutional purposes it must be noted that UPSI was initially named World Wide Design Services Consortium (WWDSC), and that is the philosophy behind this collaborative academic activity.

7. CONCLUSIONS

The starting point for setting up an international, multidisciplinary educational project for solving social problems using ubiquitous technologies was the observation that (i) the area of UT and CPS is still under-emphasised in the educational curriculum of the design and technical educations and (ii) the awareness of problems in everyday social life, that can be solved using mentioned technologies is low in general. We concluded that the following issues should get more attention: (i) UT and CPS, (ii) possible applications, (iii) awareness for social needs and (iv) responsibility for the consequences of applying CPS in society.

After four runs of the UPSI project, including the WWDSC, which was the name of the first UPSI project, this assumption turned to be valid. We found that the intended set up of the course works well if a few conditions are fulfilled, such as no forming of sub-teams inside an existing team, reliability towards the team and a fully functional cooperation. The results in terms of the development of the design competence, mentioned in section 2, were promising in the sense of (i) increased awareness and alertness (society, dehumanisation, etc.), (ii) knowledge of real needs in society, (iii) knowledge of UT, (iv) improved attitudinal aspects inside the teams (responsibility, reliability, cooperation, creativity, etc.), (v) the development of inter-disciplinary skills and experience. We have seen that inter-disciplinary borders were crossed, resulting in for instance social research done by technical students.

Some recommendations for undertaking projects like these:

- The level of English must be sufficient for informal and professional communication,
- The technical means of communication must work flawlessly, otherwise much time, interest and involvement will be lost,
- Avoid differences of time zones more than 10 hours,
- Always include a period of time where the teams can come together (final workshop),
- The obligation of giving a public demonstration gives a drive to really create and finalise a working prototype to show the realisation of scenarios and thus to validate the results.

If educational multi-x projects as mentioned in this paper are organised we think that the chance of a successful realisation will increase if particularly the internal communication and the communication between team and coach are without compromise. We have seen that reduced communication is the main factor indeed for failing projects.

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References


