Using problem based learning to support transdisciplinarity in an HCI education

Nordahl, Rolf; Serafin, Stefania

Published in:
Proceedings of HCIed (HCI in education) conference

Publication date:
2008

Document Version
Publisher's PDF, also known as Version of record

Using problem based learning to support transdisciplinarity in an HCI education

Rolf Nordahl
Medialogy, Aalborg University Copenhagen
Lautrupvang 15
2750 Ballerup, DK
rn@media.aau.dk

Stefania Serafin
Medialogy, Aalborg University Copenhagen
Lautrupvang 15
2750 Ballerup, DK
sts@media.aau.dk

ABSTRACT

In this paper we advocate the development of transdisciplinary educational programs with a strong focus on HCI, which use problem based learning (PBL) as a teaching methodology.

We describe a novel education called Medialogy, developed at Aalborg University Copenhagen in Denmark, outlining through different case studies how PBL supports transdisciplinarity.

Categories and Subject Descriptors

H.1.2 [**Information Technology and Systems**]: User/Machine Systems; H.5.2 [**Information Interfaces and Representation (HCI)**]: User interfaces.

Keywords

Transdisciplinarity, Problem Based learning (PBL).

1. INTRODUCTION

In 2002 Aalborg University Copenhagen introduced the Medialogy education, which sought to train graduates with a firm understanding of developing media technology while maintaining focus on topics there are interconnected but often overlooked in traditional engineering educations, and with the goal of training problem solvers in a digital age independent of tasks. The name Medialogy (Medialogi in danish) derives from the world *Datalogi*, which is the danish term for computer science. In Medialogy, students learn theories and applications of media technology, and develop both technical and creative skills in this field.

The education was initially introduced as a means to provide a Bachelor degree to students educated in Denmark under a two-years degree called multimedia design. However, over the years it has evolved to a full five years curriculum, and has gradually moved away from a simple joined combination of different disciplines towards transdisciplinarity. This process has been facilitated by the problem based learning (PBL) pedagogical approach, on which Medialogy is based. PBL has been adopted at Aalborg University since 1974, when the university was established [12, 13].

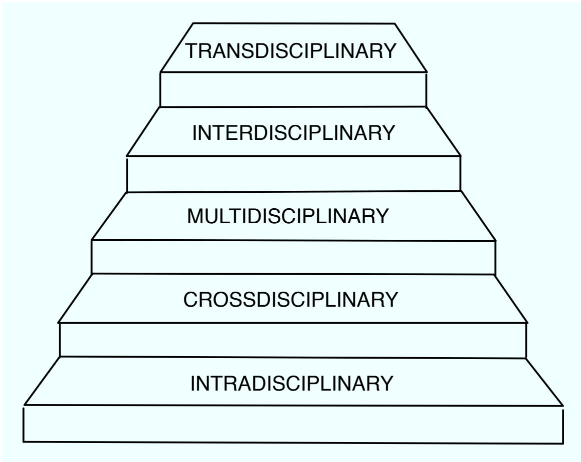

Figure 1: Representation of the hierachical structure proposed in [16].

One of the principles behind PBL is the fact that successful students need to be able to identify and untangle problems, cooperate with others and have a strong knowledge of their own and related fields. One of the key elements of PBL is problem solving through project work in groups. Each semester of the education has a specific theme, and students are asked to define a problem which addresses such theme.

In this paper, we describe how PBL helps supporting interdisciplinarity and transdisciplinarity, and discuss our reflections behind the development of the Medialogy education. We believe that in this new era of integration, teaching primarily consists of providing methods and techniques to the students so that they can obtain knowledge through project work, rather then traditional lectures. In PBL, the instructor plays the role of facilitator rather than fact introducer, and students are encouraged to choose among the different disciplines those in which they want to acquire a deeper knowledge.

2. TRANSDISCIPLINARY STUDIES

In recent years, a number of interdisciplinary educations in HCI and related fields have been developed worldwide [18, 8]. However, it is still a challenge to design a coherent, comprehensive, and interdisciplinary curriculum [1, 15]. As a matter of fact, many interdisciplinary educations show merely a combined effort of different competences from several faculty members put together. It is also a challenge to find the core competences in a curriculum which is designed for students which can show interest towards different aspects of HCI such as the engineering side, the design, or human factors. Moreover, the challenge of establishing a fruitful collaboration between different profiles is also still open [20, 3], and applies to both students and faculty members.

As an attempt to bridge the gap, in [18], Pausch and Marinelli describe how in their Master education they started by teaching basic programming to artists, and humanistic subjects to computer scientists. However, this solution did not prove to be ideal. Instead, they preferred to mix the different profiles during project work.

The terms *interdisciplinary* and *transdisciplinary* are often used interchangeably. In this paper we adopt the definition proposed by Meeth in 1978 [16]. Observing the existing confusion in defining what an interdisciplinary education is, Meeth proposed a hierarchical classification, illustrated in Figure 1. At the bottom of such hierarchy he placed intradisciplinary studies, i.e., studies composed of a single discipline. At a higher level we find crossdisciplinary studies, i.e., studies in which one discipline is viewed from the perspective of another. An example of crossdiscipline is, as Meeth mentions, the study of physics of musical instruments. Crossdisciplinary studies are relatively easy to establish, since they allow faculty members to remain in their own disciplines. At the next level he placed multidisciplinary studies, i.e., the juxtaposition of disciplines, each offering their own viewpoint, but with no attempt of integration. One level higher shows interdisciplinary studies, which attempt to integrate in a coherent and harmonious curriculum several disciplines which allow to solve a particular problem. According to Meeth, the highest level of integrated studies is transdisciplinary studies. Such studies go beyond disciplines, since they start from a problem and, using problem solving, they bring the knowledge of those disciplines which contribute to the solution [16]. Therefore, as shown in Figure 2, while interdisciplinary studies start from a discipline and develop a problem around it, transdisciplinary studies start from a problem and find the related disciplines which facilitate solving it. As also argued by Meeth, transdisciplinary studies are hard to design, since they require highly prepared and intellectually mature faculty members as well as students.

Interdisciplinary and multidisciplinary curricula developed and in use today represent initial steps on the road to a transdisciplinary curriculum. However, these older concepts largely involve including traditional courses from two or more disciplines in a curriculum. There is usually little or no attempt to make individual courses multidisciplinary and blend the concepts from various disciplines together. Neither traditional textbooks nor university course organization make it easy to develop and deliver true transdisciplinary

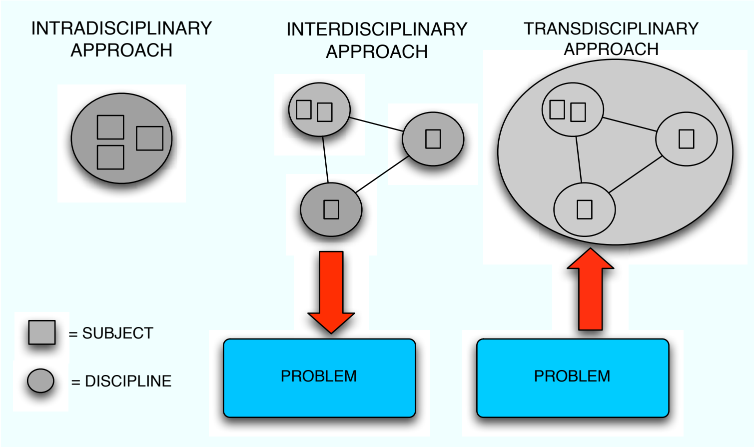

Figure 2: Disciplinary systems. Adapted from [6].

courses. However an ideal transdisciplinary curriculum consists of true transdisciplinary courses. Boundaries for transdisciplinary courses should be the boundaries of the problem being addressed, not the artificial boundaries of disciplines. A transdisciplinary course must involve multiple faculty or mentors so that the concepts covered can be presented from several perspectives and so that the integration of knowledge, skills and jargon can be more fully appreciated by the students. Each course should include project or laboratory exercise modules through which the course material will be presented and put into practice.

3. MEDIALOGY AND PBL

The Medialogy education is an education in media technology organized over 10 semesters. Six semesters are dedicated to the Bachelor level, while four semesters to the Master level. The first two semesters of the education, called Basis year, are standardized by Aalborg University for all engineering studies. The remaining eight semesters have been carefully designed by the founders of the Medialogy education since its inception.

Each semester has its own theme, which is supported by different mandatory courses. The skills provided in the courses are determined by the faculty members in order to support the semester project. The theme of the third semester is *Human Senses, Digital Perception*. Students learn principles of human perception and computer vision, as well as skills in mathematics, programming and aesthetics and design. The theme of the fourth semester is *Interaction Design*. Students learn how to design and evaluate interfaces embedded with sensors, which have a significant auditory feedback. The theme of the fifth semester is *Animated Environments and Visual Effects*. Students learn theories and techniques behind computer graphics, screen media and animation. The theme of the sixth semester is *Interactive media systems*. During this semester, students work on their Bachelor thesis. From the 7th to 10th Semester, students work on a Master education. During the Master education, students have possibility to choose courses to follow, which is not possible during the Bachelor education. The theme of the seventh Semester is *Merging of the Senses*. Students learn how the human brain processes and combines information arriving to different senses, and how multimodal systems can be simulated. The theme of the eight Semester is *Immersion and Interactivity*. Students learn how to design immersive virtual worlds. On the ninth Semester, students are encouraged to spend a semester abroad or to work in an internship in a company. The tenth Semester is fully dedicated to the Master thesis.[1]

In each Semester, the project requires approximatively 500 hours of workload per student. Students work in a group of about 6 people at the Bachelor level, and about 3 people at the Master level. Master thesis are usually carried out individually or by couples of students.

In the Medialogy education we adopt the PBL methodology to train students and faculty members to evolve from crossdisciplinary and multidisciplinary to interdisciplinary and transdisciplinary.

PBL becomes interesting when a variety of disciplines need to be incorporated to address the problem. We structure problems in such a way that students are able to integrate and apply knowledge from different disciplines. This allows students to see connections among disciplines and promote carryover of knowledge from one discipline to another. In this situation, PBL facilitates transdisciplinarity, since students are exposed with a problem, and need to find the relevant disciplines and connections among them which allow to solve the problem. As it will be shown in the different case studies described, they are all transdisciplinary in nature, since they start from a given problem, and use several disciplines to address it and solve it.

Another positive element of PBL is a higher degree of learning; PBL projects require a high level of social, communication and co-operative skills among students. These skills are highly demanded in the professional work. Given the high amount of workload which a project requires, usually the final results are very satisfactory. PBL has been widely adopted in several educations worldwide, among other things for its ability to develop problem solvers and for giving the possibility to students to work in groups solving issues close to the real world. PBL has especially proven to be particularly suitable for educations dealing with design of interactive system [21] and multidisciplinary settings [11].

The main challenge encountered was to move away from a multidisciplinary education towards a coherent transdisciplinary one with a defined identity. We achieved this goal by identifying the key competences of next generation HCI experts, from the technical and human factors point of view. This goal was achieved in different ways. One way that proved to be quite effective was to create teams of projects supervisors, each coming from a different background. As an example, students are usually supervised by both a contextual and a technical supervisor. The contextual supervisor is mainly responsible for the problem analysis and problem formulation phase, while the technical supervisor is responsible for problem solving. Both supervisors are present at all meetings, which are usually held weekly, and are required to be prepared in all the components of the project. Both supervisors assess the students at the end of the semester. This approach is particularly beneficial for those faculty members previously trained in unidisciplinary educations.

As also stated in [6, 7], the first step in achieving a transdisciplinary education is to extract common elements, methods, design and processed from existing disciplines and synthesize them into the foundations of the new transdiscipline. We believe that this is an extremely important and complex task, but fundamental to allow the shift from multidisciplinarity to transdisciplinarity.

The integration of disciplines is still a work in progress, but we realized that a somehow imposed communication and co-supervision between faculty members whose disciplines are usually kept apart was extremely beneficial for both students and instructors, and solidified the identity of the education.

As an alternative to finding a single Renaissance individual with all the skills required, we believe there is a need for individuals who have expertise in forming problem-solving teams and functioning effectively within those teams. In Medialogy, we encourage students to approach HCI from the "big picture", and we developed our program in order to attract individuals who appreciate conceptual approaches to problem solving, critical thinking and creativity.

The starting point of a project in the bachelor education is usually interdisciplinary, in the sense that a problem which uses the competences learnt during the semester is formulated. At the Master level, the approach becomes transdisciplinary, since students address a problem of their interest and then find the relevant subjects which help them solving the problem. Students design and develop an interactive system which addresses the problem, and then evaluate the application to see if the problem has been solved.

We expose students to different design methodologies [9], developing their ability to choose among them the most suitable for their current problem. Evaluation techniques also evolve during the course of the education. Students start from simple questionnaires, interviews, and usability studies [19], to more elaborate evaluation techniques such as presence questionnaire [26].

A recurrent issue is how to evaluate media art projects [10] and how design and evaluation interrelate in students' projects [24]. In the following section, we describe different projects completed by Medialogy students, and show how these issues were addressed. The projects are organized in chronological order according to the semester in which they took place. Projects range from alternative interfaces for computer games, to art installations or new musical instruments.

Although the context of the different projects is rather different, they all have in common the definition of a problem and problem analysis, the design of an interface which addresses such problem and the evaluation of the system.

4. CASE STUDIES

4.1 Wobble active

The problem addressed in this project is how to enhance the user experience and entertainment factor while training

[1]More information about the Medialogy education can be found at www.media.aau.dk.

and rehabilitating ankles. This project was completed in 2007 during the 4th Semester under the theme *Interaction design*.

The problem was addresses by combining different competences acquired during the semester, such as the ability to design and evaluate interfaces embedded with sensors, and produce interactive auditory feedback. More precisely, they enhanced a traditional wobble board in such a way that it could be used as an alternative controller for computer games. In the first game, subjects were asked to maintain balance on the board, while in the second game, subjects were asked to navigate in a maze.

Testing of the interface was planned according to the DECIDE framework [19]. Six subjects tried both games. Half of the subjects found the balancing hard to achieve, and five out the six subjects found the maze game more difficult than the balancing one.

A professional physiotherapist was also consulted, who was positive and enthusiastic about the possibility of using the enhanced Wobble board for training.

Figure 3: From the Wobble active project. 1 Top view, 2 side view, 3 wobble active in action, 4 the bottom.

This project presents a particularly clever and elegant solution to the general problem of boredom during physical exercise, in this case strictly applied to ankle rehabilitation.

In this situation, students chose a transdisciplinary approach, since they defined a problem and then looked for the relevant disciplines which allowed to solve it. However, as is often the case during the Bachelor education, the transdisciplinary approach is usually limited to the disciplines learnt during the semester. It might be argued that the approach is mostly interdisciplinary, since students tend to examine the available disciplines encountered during the semester, and build a problem around it.

In this example, PBL allowed the students to think in terms of solving the problem of helping people to enjoy rehabilitation, instead of simply building an alternative game controller (problem based versus product based). The success criteria needed a longer testing time which was not possible given the timeframe of the project.

4.2 The Soundgrabber

The problem addressed in this project was to what degree it is possible to make sound tangible by means of an untangible user interface.

To address this problem, and installation called the *Soundgrabber* was developed. As can be seen in Figure 4, the Soundgrabber is a physical interface designed as a semicircle. At the top of the semi-circle, four columns are placed. At the bottom of each column a speaker is installed. Each column is embedded with light sensors, which allow to detect the position of the hand of the user moving vertically parallel to the column.

Moreover, a bucket is placed in the center of the semi-circle. The user interacts with the Sound grabber using a glove embedded with a bend sensor. By bending the hand inside the bucket, the user is able to grab a sound, listen to it (thanks to the speaker embedded inside the glove) and release it in one of the columns. The Soundgrabber is therefore an interactive installation where users can grab different sounds and place them in different locations.

Figure 4: The Soundgrabber was publicly displayed at the Sound Days event in Copenhagen in June 2007.

The problem formulation was addressed by allowing users to play with it, and then answering a questionnaire inspired by the sensory substitution presence questionnaire, based on a

1 to 5 Likert scale [4]. In such questionnaire, statement such as "I felt that I was able to grab a sound" or "I felt that I was able to relocate the individual sounds" were formulated, and subjects were asked to answer in a scale from 1 to 5 if they agreed or not with the statement. Results showed that the sensory substitution between audition and touch worked, since there was a statistically significant amount of subjects who felt they were able to move sounds around and grab them.

Being an art installation, Soundgrabber was also publicly demonstrated at the Sound Days event in Copenhagen in June 2007. Sound experts and naive visitors tried the installation, and provided enthusiastic feedback. Figure 4 shows two of the developers and a visitor playing with the interface at the event.

As in the previous example, students defined a problem, and then used different disciplines such as sensors technology, physical interface design and audio design to address it. PBL helped formulating the question addressed by the students, i.e., how can sound made tangible. The Soundgrabber is one of the possible solutions to such question.

4.3 Virtual reality bowling game

Moving towards higher semesters, students become more aware of the complexity of interaction among different human senses, both when designing new HCI systems and evaluating their cognitive implications.

As an example of problems addresses in higher semester, students investigated if the lack of haptic feedback in a virtual environment can be substituted by properly designed auditory and visual feedback.

The virtual reality bowling game is a project developed during the 7th Semester (first semester of the Master education) in the Fall 2006, under the theme *Merging of the senses* which addresses the questions just described.

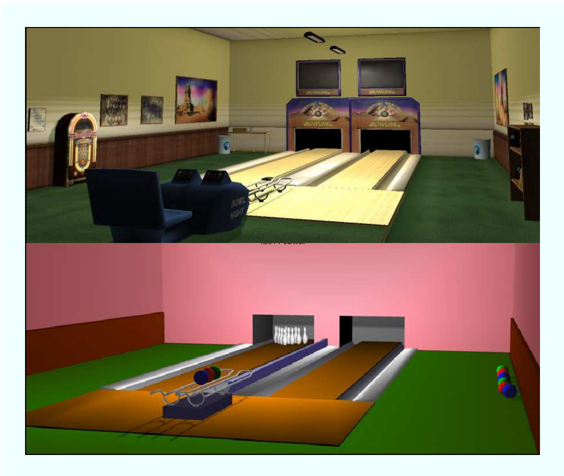

Figure 5: From the VR bowling game. Top: high quality visual display. Bottom: low quality visual display.

By building a virtual bowling game, the interdependency between the sense of presence and pseudo-haptics [14] was investigated.

Figure 6: A subject interacting with the VR bowling game.

As shown in Figure 5, two visual environments were designed, one with detailed high quality rendering, and one will low quality rendering. In the high quality virtual environment, different elements were carefully rendered. In the low quality environment, only basic elements such as the bowling alley were reproduced. The experiment was set up as a bowling game where users competed against each others for a prize. The environment included three balls, each with their own weight simulated using the C/D ratio technique as described in [14].

The visual display was implemented in Virtools[2] and rendered through an head mounted display. As shown in Figure 6, subjects were interacting with the environment using a glove enhanced with sensors. The position of the subjects was tracked by using a Polhemus 3Space tracker.[3]

20 undergraduate students participated to the experiment, under the heading *Virtual Bowling*. The users were exposed to one of the two virtual environments and given a practise round of 9 bowling balls before the actual game and test started. Here each user again had a total of 9 bowling balls, 3 of each weight, and was basically only instructed to hit as many cones as possible in the virtual bowling competition. Following the test experiment each participant was given a questionnaire of 37 items. The questionnaire is a modified version of Witmer and Presence Questionnaire (PQ) merged with the Immersive Tendencies Questionnaire (ITQ) Singers [26]. Results showed that there was not significant difference between the two environments, and subjects reported a sensation of pseudo-haptics less significantly than expected.

The project was featured in the national danish television show "Good morning Denmark", in a special broadcast con-

[2] www.virtools.com/

[3] www.polhemus.com

cerning haptic interfaces.

In this project, the problem of interest is the possibility of replacing haptic feedback by using other modality, phenomenon also known as sensory substitution. Students chose to address this problem by developing an application, in this particular case a game.

4.4 PHYSMISM

The PHYSMISM, shown in Figure 7, is the result of a Master thesis completed in February 2007. In the Medialogy education, a Master thesis is a one semester project during which students follow no courses. The approach used in working on a Master thesis is transdisciplinary, since students choose a problem of their interest and then find the relevant disciplines which allow them to solve the problem.

The main problem addessed by the PHYSMISM is the lack of creativity shown by musicians while using a sound synthesis technique called physical modeling [23]. Physical models of musical instruments have been widely researched by engineers, computer scientists and acousticians. However, their musical possibilities have not been investigated yet. The question asked by the students is to what extent is it possible to enhance the creative possibilities offered by this synthesis technique.

As can be seen in Figure 7, the PHYSMISM is a novel hardware interface in which several physical models are implemented. Among them, a friction model such as the one found in a bow exciting a string, an aerodynamic model like a person blowing into a flute, a stochastic model similar to the one simulating playing a maracas, and an impact model typical of percussion instruments are implemented.

Figure 7: The final look and feel of the PHYSMISM was among other things inspired by old analogue synthesizers.

Different sensors allow to track the gestures of the player and use them as input parameters of the different sound synthesis algorithms.

The PHYSMISM interface was tested by 11 professional musicians. The musicians were asked to get familiar with the interface for approximately 25-30 minutes and try to understand the possibilities of the instrument.

Positive	Negative	Application
Many parameters		Friction
	Few parameters	Impact
	Predictability	Impact
Unpredictability		Friction
Low frequencies		Impact
Combined models		Friction+Impact
Bi-manual control		Physical interface
Natural interaction		Physical interface
Clear interaction		Crank

Table 1: Summary of the positive and negative features of the different physical models as expressed by the test subjects.

After the short practice session, subjects were asked to improvise with the PHYSMISM for about five minutes. During the whole test period, observations and additional comments from the test persons were annotated. After having practiced with the instrument, test subjects were asked to fill in a questionnaire. Although data from musicians were recorded, they proved to be too diverse to be used for a proper quantitative analysis. However, interesting qualitative results were gathered, which provided useful guidelines for the design of novel musical interfaces embedded which sensors which use physical models. Table 1 summarizes such results. More detailed information concerning this project can be found in [5].

In this project students adopted a transdisciplinary approach, since they wanted to understand how to engage musicians in using sound synthesis techniques usually adopted mostly by engineers and acousticians. They also wanted to understand if a tangible user interface enhances playability of virtual musical instruments, compared to a graphical user interface. To address the problem, they developed skills in interface design an development of sound synthesis algorithms.

4.5 Self-sound in virtual reality

The project *Self-sound in virtual reality* is also the result of a Master thesis completed in January 2007. As in the previous project, the student adopted a transdisciplinary approach.

This project explored to what extent auditory rendering enhances sense of presence and self-motion in virtual environments.

The problem formulated was tested by designing a photorealistic virtual environment. This environment was designed by using the image based rendering technique [2], which was delivered to the subjects by using an head mounted display, as shown in Figure 8. The environment was enhanced with different auditory cues. Subjects visiting the environment were asked to wear a pair of sandals enhanced with pressure sensitive sensors. Such sensors were connected in real-time to a sound synthesis engine, and the self-sound of subjects walking around the environment was synthesized in real-time using physical models. Moreover, the position of the subjects in the environment was tracked in real-time using a Polhemus magnetic tracker. Six different auditory environments were designed. The environment presented a music track and the different combinations of a static soundscape, a dynamic soundscape in which sounds were positioned according to the position of the subjects in the environment and a soundscape with real-time synthesis of walking sounds of subjects in the environment.

140 subjects tried the six different auditory environments. The motion of the subjects was recorded for further analysis. Moreover, after visiting the environment subjects were asked to fill in a presence questionnaire. Such questionnaire was carefully designed by combining several established questionnaires in the field [26, 22, 25]. Quantitative results show that motion significantly increased when a dynamic soundscape and the self-sound of subjects' own footsteps was present in the environment. Moreover, analysis of the presence questionnaire's results showed that subjects reported a strong sense of presence in the dynamic auditory environment. This project won a prize at the Danish SigCHI student price competition for best Master thesis in Denmark 2006. More information related to this project can be found in [17].

Figure 8: A subject during the experiment in self sound in VR.

5. CONCLUSIONS

In this paper we analysed the foundations of the Medialogy education, and illustrated different case studies which are the result of students' projects. We believe that PBL provides a coherent framework inside which students can express their creativity in the design of novel human computer interaction paradigms. The projects described, infact, largely vary in the contextual issues they address, and they reflect the interests of the different groups of students. Technology is not anymore the main issue in designing novel interactions between humans and computers. Nowadays, it does not require highly skilled engineers to fully develop novel interfaces for different applications ranging from entertainment, art or rehabilitation.

While progressing through the education, students get exposed to more and more advanced technical aspects involved in the design of interactive systems, starting from simple computer vision algorithms, and moving to sound processing, sensors technology, computer graphics, artificial intelligence and virtual and augmented reality technology. They also learn how to integrate such technologies, which becomes an issue especially when projects become rather complex as it is the case during the Master education.

An evolution of the students' ability to reflect and work problem based is also achieved by developing their contextual skills and their evaluation techniques, offering courses in media sociology, measurement of user experience, interactive media theory and human perception and cognition. In Medialogy, we particularly value the ability of PBL to train problem solvers as opposed to users of tools, which is what the market needs.

We believe on the importance of supporting and offering true transdisciplinary semesters, where boundaries are the problem being addressed and not the boundaries of disciplines. Within the semester, each course can be considered as intradisciplinary. The next step would be to support transdisciplinary courses inside a transdisciplinary semester.

We experimented in this direction by offering a transdisciplinary course in measurement of user experience, in which different approaches to evaluation of HCI products were offered, ranging from qualitative approaches such as focus groups and observations, to more quantitative evaluations such as questionnaires and physiological measurements of users' feedback. Students were exposed to different evaluation techniques, and asked to critically analyze, compare and choose the most suitable for their problem. Such overview of different approaches received positive comments from the students.

6. REFERENCES

[1] P. Adamczyk and M. Twidale. Supporting multidisciplinary collaboration: requirements from novel HCI education. *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 1073–1076, 2007.

[2] H. Bakstein and T. Pajdla. Rendering novel views from a set of omnidirectional mosaic images. *Proceedings of Omnivis 2003: Workshop on Omnidirectional Vision and Camera Networks*, page 6.

[3] C. Bartneck and M. Rauterberg. HCI realityÑan 'Unreal Tournament'? *International Journal of Human-Computer Studies*, 65(8):737–743, 2007.

[4] F. Biocca, J. Kim, and Y. Choi. Visual Touch In Virtual Environments: An Exploratory Study of Presence, Multimodal Interfaces, and Cross-Modal Sensory Illusions. *Presence: Teleoperators & Virtual Environments*, 10(3):247–265, 2001.

[5] N. Boettcher, S. Gelineck, and S. Serafin. PHYSMISM: a control interface for creative exploration of physical models. *Proceedings of ACM New Interfaces for Musical expression*, 2007.

[6] A. Ertas. Transdisciplinary engineering education and research model. *Journal of Integrated Design and Process Science*, 4(4):1–11, 2000.

[7] A. Ertas, T. Maxwell, V. Rainey, and M. Tanik. Transformation of higher education: the transdisciplinary approach in engineering. *Education, IEEE Transactions on*, 46(2):289–295, 2003.

[8] C. Giovannella. Design, Technology, Scientific and Humanistic cultures: filling the gap.

[9] S. Harrison, M. Back, and D. Tatar. " It's Just a Method!": a pedagogical experiment in interdisciplinary design. *Proceedings of the 6th ACM conference on Designing Interactive systems*, pages 261–270, 2006.

[10] K. Höök, P. Sengers, and G. Andersson. Sense and sensibility: evaluation and interactive art. *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 241–248, 2003.

[11] J. Kimmons and P. Spruiell. Using Problem-Based Learning in a Multidisciplinary Setting. *Clothing and Textiles Research Journal*, 23(4):385, 2005.

[12] A. Kolmos, L. Krogh, and F. Fink. *The Aalborg PBL model: progress, diversity and challenges*. Aalborg University Press, 2004.

[13] L. Larsen, S. Andersen, F. Fink, and E. Granum. Teaching HCI to Engineering Students Using Problem Based Learning. *INTERACT Workshop of IFIP WG*, 13.1.

[14] A. Lécuyer, J. Burkhardt, and L. Etienne. Feeling bumps and holes without a haptic interface: the perception of pseudo-haptic textures. *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 239–246, 2004.

[15] W. Mackay. The interactive thread: exploring methods for multi-disciplinary design. *Proceedings of the 2004 conference on Designing interactive systems: processes, practices, methods, and techniques*, pages 103–112, 2004.

[16] L. Meeth. Interdisciplinary studies: A matter of definition. *Change*, 7:10, 1978.

[17] R. Nordahl. Auditory rendering of self-induced motion in virtual reality. *M. Sc. project report, Dept. of Medialogy, Aalborg University Copenhagen*, 2005.

[18] R. Pausch and D. Marinelli. Carnegie Mellon's entertainment technology center: combining the left and right brain. 2007.

[19] J. .-. Preece, Y. Rogers, and H. Sharp. *Interaction design: beyond human-computer interaction*. Wiley, 2002.

[20] G. Rauterberg. HCI as an Engineering Discipline: to be or not to be!? *African Journal of Information and Communication Technology*, 2(4):163–184, 2006.

[21] N. Schultz and H. Christensen. Seven-step problem-based learning in an interaction design course. *European Journal of Engineering Education*, 29(4):533–541, 2004.

[22] M. Slater. Measuring presence- A response to the Witmer and Singer presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 8(5):560–565, 1999.

[23] J. Smith III. Physical Modeling Using Digital Waveguides. *Computer Music Journal*, 16(4):74–91, 1992.

[24] C. Wania, M. Atwood, and K. McCain. How do design and evaluation interrelate in HCI research? *Proceedings of the 6th ACM conference on Designing Interactive systems*, pages 90–98, 2006.

[25] B. Witmer and M. Singer. Measuring Presence in Virtual Environments. 1994.

[26] B. Witmer and M. Singer. Measuring presence in virtual environments- A Presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3):225–240, 1998.