Developing Health Technology Innovators: A collaborative learning approach

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Abstract— In this paper we present a new initiative to promote collaborative learning through industry partnered, interdisciplinary, student and user centred projects. This was achieved through the development of rehabilitation devices augmented with gamified software. Today development of software systems often requires people from different specialities who can work in multidisciplinary teams to achieve a common objective. A key challenge, therefore, is producing graduates with an understanding of a number of disparate skills across many discipline boundaries. Undergraduates may be knowledgeable in one specific discipline but will not be aware of the issues brought to bear by other relevant disciplines. In an effort to overcome this limitation, a cross-discipline course "Serious Games and Welfare Technology" was developed that allows students from different disciplines to work together to produce innovative, technology-supported health solutions. The course, an EU funded Erasmus+ initiative, was supported by a MOOC and enabled multi-disciplined and multinational teams to produce solutions for leading Health technology companies in the areas of rehabilitation and aging support. Following the first year of offering the course with a cohort of students from 5 countries, we report on the experiences and outcomes achieved from a number of viewpoints.

Keywords—Exergame, MOOC, collaborative learning, gamification, multidisciplinary, project-based learning, serious games, gamification, collaborative learning, multidisciplinary, international teams, welfare technology, online

I. Introduction

The Strategic partnership project *Serious Games and Welfare Technology* has run over 2 years from 1. Sept 2016 to 31. Aug 2018. In total 23 students and 14 professors from five Higher Education Institutions (HEIs) and four company partners participated in this project. The different disciplines involved were Human Movement Science, Occupational Therapy, Software Development, Game Design, Computer Games Development and Electronic Engineering. Four multinational and multidisciplinary teams of undergraduates were assigned to work on products for industry partners across four countries.

The project partners were: NTNU (Norwegian University of Science and Technology) which was the project coordinator, FHV (Fachhochschule Vorarlberg), HBRS (Hochschule Bonn-Rhein-Sieg), ITC (Institute of Technology Carlow), HvA (Stichting Hogeschool van Amsterdam). The other partners involved were: 3D Motion Technologies AS (real time human motion capturing and gait analysis), MotekForce Link (clinical gait analysis and training), Sozialdienste Götzis (social services, care and support), and Salaso Health Solutions Limited (physical rehabilitation and wellness). In addition, a number of healthcare organisations were assisted with the project.

One of the great challenges of our time is keeping people healthy throughout their lifespan. Many European countries are experiencing an increase in life expectancy [1] and therefore an increasing cost to healthcare [2]. One has to look at new options for rehabilitation or the maintenance of public health. This brings new challenges to the healthcare system both in caring for the elderly as well as in rehabilitation programmes. Increased focus on the use of serious games to promote physical activity is part of the answer to these challenges. The European Commission views enabling technologies as the most important driver for modernization of European industry and the transition to a knowledge-based, sustainable society [3].

Multidisciplinary cooperation between technology and different health disciplines is a precondition for innovation in this area. It is also a precondition for developing technological solutions to address social challenges and enabling related industry. Fall prevention, increased focus on physical activity and mental health, and training in rehabilitation institutions or in-home settings are examples of possible applications for serious games, exergames or gamification.

The aim of this project was to promote collaborative learning through industry partnered, interdisciplinary, student and user centred projects and develop innovative solutions within welfare technology. The prototype assignments were specified by the affiliated companies and related to welfare technology.

II. LITERATURE REVIEW

A. Collaborative learning

When designing student-based learning approaches in an international context it is important to reexamine the concepts of learning. Many learning theories refer either to the external interaction between the learner and her social, cultural or material environment or to the internal psychological process of knowledge acquisition, these being psychomotorically, cognitive or social. Traditional behavioral cognitive theories on learning, like constructivism [4, 5] emphasize the cognitive learning process, while concepts of situational learning [6] or social constructionism [7] emphasize the external social process. Illeris[8] merges these two approaches in his learning theory into a three dimensional learning model, in which the interaction between the learning individual and the environment are posed on a vertical axis and the internal learning process of the individual is posed on an horizontal axis. According to Illeris the dimensions are dependent and interwoven: the gaining of knowledge and skills is dependent on mental stability of the learner and at the same time this stability is influenced by what is learned. The value and duration of the learning is often dependent on emotional factors within the learning process. Participation, communication and collaboration in a learning environment or community are important success factors for learning and contribute to the social development of the learner.

Cognitive constructivism tells us that learning is a natural process taking place in a realistic context with relevant tasks. Self-direction and ownership of the learning process will improve the learning outcome [9,10]. Students that are regulating their own learning process are active members capable of setting goals. These students are apt to adjust their motivation and learning behaviour to accomplish their goals and to evaluate whether they are making the appropriate progression towards the end goal [11,12]. Knowledge construction is a collaborative process which aims to produce new understanding or knowledge which exceeds something that anyone alone could achieve. It is also essential that knowledge construction is based on each other's ideas and thoughts [13].

B. *Massive Open Online Course (MOOC)*

Collaborative learning processes with MOOCs were investigated in literature concerning pedagogical approach. Instructional design was thereby based on either connectivism (cMOOC) or behaviorism (xMOOC) [14].

Connectivism refers to the fact that the knowledge should be presented to the learners so that they make connections between the new information and what they already know about the topic. Collaborative learning and social connection/networking are principles covered by this approach. However, innovation processes involving functional prototyping in interdisciplinary teams demand constructivist methods at certain points. MOOC learners should be offered active learning, according to which knowledge will be constructed not just presented. In fact, MOOC research emphasizes the importance of the socio-constructivist approach in general [15] for improving success rates.

Aside from teamwork and social networking it is known that problem-based learning, peer assistance, learner empowerment and appropriate use of different media are key design elements of MOOC learning experiences [16]. Comprehensive literature analysis by Veletsianos & Shepherdson [17] showed that there is limited research reported on instructor-related topics, and that even though researchers have attempted to identify and classify learners into various groupings, very little research examines the experiences of learner subpopulations. Results from a recent systematic review by Zhu et al. [18] did further reveal that for most MOOC research projects authors worked within the same country.

III. METHODS

The projects followed an agile/iterative learning model and were linked into each HEI's curriculum to satisfy the academic requirements for the students. Fig. 1 shows the learning model used for this project and illustrates how the students progressed from the initial briefing of the problem to developing the final product - a functional exergame. We will elaborate further on each component of the model.

The students enrolled on the project came from different disciplines and needed to get a common understanding of what creating a serious game prototype implied. The first activity for each individual student was therefore to follow an online course, specifically designed to teach both healthcare and technological students about how to create exergames. This ensured that all the students had common ground to build upon before working together to develop their exergame-prototype.

The students were split into multinational and multifunctional teams. Each team was assigned to a project proposed by a company from the health care sector. As shown in Fig. 1 the students collaborated both co-located and distributed whilst working on their serious game prototype. During this working phase the teams received feedback on their prototypes from the teachers and the companies' representatives and they also conducted user trials on real patients and collected data from these trials. For the final period some of the students continued developing their exergame as part of their graduation project. The students from abroad used Erasmus+ mobility funding to support their travel and cost of living.

To evaluate the students' learning outcomes an online survey was completed after each project activity. The project's overall quality evaluation was performed by an external company (Bergstrøm Consult)

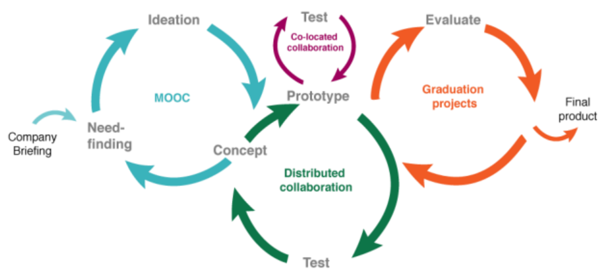

Fig. 1. The Collaborative Learning Model

A. *MOOC*

To begin the learning process, we provided the students with introductory course material on each of the subject areas relevant to the project work they would be undertaking. The HEIs prepared recorded lectures and curated the necessary learning materials (e.g. online videos, presentations, academic papers) all of which were made available through the Canvas Learning Management System (LMS). Given the disparate student backgrounds it was necessary to present this material at a level which all students could comprehend and appreciate. This allowed all students to gain at least an introductory level of knowledge in all topics, while students from each specialisation would then be expected to take the lead in any further research needed for the projects. Prior to the first international meeting, all students were asked to complete the online course. Each module on Canvas included a number of evaluation tasks for the students in the form of online quizzes and small projects. The modules were structured as follows:

- Real time human motion capturing and analysis
- Gamification in everyday life situations
- Safe system development and implementation
- Game design with sensors. Human Centered Design

B. Distributed Collaboration

Each project team consisted of five students where each team member came from both a different HEI and a different undergraduate specialisation. This meant that every team contained one student from each of the participating countries. Although mentoring was provided to the teams throughout the year, the teams were expected to be self-organising and had to develop their own tools and structures to allow efficient team work during all stages of the project.

C. Co-located Collaboration (International weeks)

October 2017: Amsterdam, Netherlands Goals: Form the international teams, summarize the MOOC modules and create project/motivation concepts. Activities: The first international meeting including the students from all countries was held at the Hogeschool van Amsterdam. A key method in the process of this international project was to form innovative teams that included a student from each discipline and country respectively. The team selection was based on the students' individual profiles and oriented around the solutions required by the companies. Accompanied by social activities and team exercises, lectures and workshops summarised the contents of the modules and covered the important project steps in the innovation process.

A focus was put on the topics needed to learn for the gamified solution. Therefore, the motivational concepts/gamification basics and the Human-Centred-Design (HCD) [19] process were discussed. The student teams were instructed to focus on the first HCD phases, inspiration and ideation, and an underlying motivational concept for the target group. At the end of the week a concept document outlining solution approaches had to be pitched to the companies by each team for feedback and refinement. In addition, the teams had to work out a schedule and determine how they would continue to collaborate from their respective home institutions.

January 2018, Bonn, Germany. Goal: Documented proof of Concept. Activities: The students met again face to face for a week to merge the work they had done during the previous semester at their home institutions into one single, functional prototype. As the Bonn meeting was the project end for about half of the students it was important that they created a final report together. The company partners were all on location to support the students and give valuable feedback on the process and the results. So each team used the whole week to:

- improve their product by merging the different code pieces and combining UI elements with physical prototypes and the software components
- prepare a presentation of their prototype
- summarize their results and findings in a final report using online collaboration tools such as Google Docs
- evaluate the current status with the company partners to find out what needed to be changed or improved in the next semester by doing tests and interviews

June 2018: Trondheim, Norway. Goal: extend the findings after evaluating the final results. Activities: Some of the students profited from the preliminary results during the summer semester 2018 by building their bachelor or master thesis upon them. They discussed their experience and findings with their current and former teammates and presented the evaluation process and final results at a public conference. Additionally, they got insights on gamification, serious games and exergaming from internationally respected professionals.

D. Graduation Projects

During the last period (3 months), five of the students went abroad as Erasmus+ mobility students to continue the work on the prototype as part of their graduation project whereas seven students joined them at their own home universities. The students tested the prototypes with the end-users and improved them to come up with their final working products (devices, interfaces, software, etc.).

Each team successfully delivered a product for their partner company. The finished products were:

- A custom wearable with a gamified interface that allowed remote monitoring of patient balancing abilities during rehabilitation (Salaso Health Solutions).
- Gamified social photography app to promote outdoor activity for the elderly (Sozialdienste Götzis).
- Exergame for lower limb stability training using the Motek DynStable (Motekforce Link)
- A treadmill based Virtual Reality exergame (3D Motion Technologies, Fig. 2)

Fig. 2. Virtual Reality Based Treadmill Exergame

IV. EVALUATION

This section presents the project experiences from the perspectives of the companies, teachers and students. The learning objectives involve experiences concerning working in interdisciplinary international teams on an exergame. Company and teacher perspectives were gathered at an evaluation meeting. Student perspectives were gathered using anonymous online surveys, an external quality expert as well as an evaluation session.

A. *Student Perspective*

The following evaluation results are based on online surveys conducted after each phase of the project. After a week working together on ideas and figuring out how to deal with the assignments from the non-academic partners (Amsterdam), as well as after working with the MOOC content, the students filled out the survey on their experience (total n=21). Fig. 3 shows a perceived increase of knowledge of about 17% after the first phase.

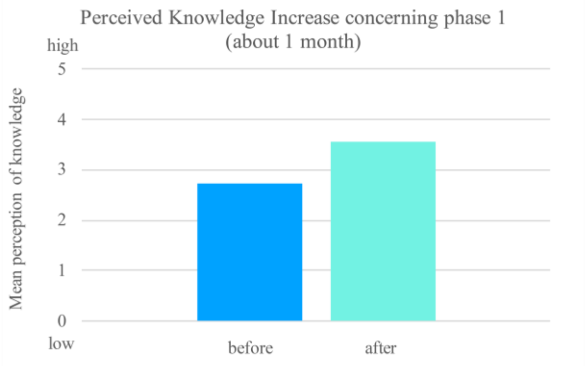

Fig. 3. Mean perception of knowledge before and after working on the MOOC and on the assignment for one month

After the prototype phase all participating students answered questions about their experience during the semester working on the prototype individually at their home institutions as well as their insights on five days together in Bonn at the end of the first semester (n=20).

75% of the students (n=15) stated that the on-location work in interdisciplinary and international teams as the favourite aspect of the prototype development. Almost the same amount of the students (n=12) found it very hard to work in international teams when not in the same place, because the different universities had different workloads and curricula what made communication and organizing meetings hard. The lack of time to work on the project was therefore a huge obstacle for half of the students (n=11). Furthermore, the lack of relevant hardware (good computers, the tools being used by the partner company, etc.) made the prototype development hard for some students/teams (n=3).

On the positive side the students mentioned useful help from the teachers (n=5) and the assignments and productive feedback from the company partners (n=15) although sometimes they would have liked a quicker response (n=2). The assignment in general and the development process, from the brainstorming session to a working prototype, were also flagged as valuable aspects of the project (n=3). Two students mentioned the importance of a team leader for achieving good results (n=2). Some students stated that they learned a lot about the relevant subjects and studies as well as the cultures of the other students (n=8). They also improved their technical and development skills (n=3), learned completely new things (n=3) or at least got a bigger picture on the overall process and possibilities of gamification and games (n=3). 60% mentioned they had learned a lot concerning teamwork and communication (n=12).

In addition, the students were asked to write down their experience as a team on post-its after the final phase and conference in Trondheim. The results underline the findings from the individual survey conducted a semester earlier. Most negative statements concerned communication and feedback (n=8), timing and practical issues (n=5), team collaboration (n=3), and the assignments (n=2). The most positive aspects pointed out were the social facet (n=11), the international teamwork (n=9), and the academic part of the project (n=8). Additionally, travelling and having fun were mentioned (n=4).

More than half of the students (total n=20) would recommend this course to others (n=12) but sometimes only under specific conditions. As seen in Fig. 4, in total 50% were happy with the course in general and rated their experience as very good (5) or good (4) (n=10).

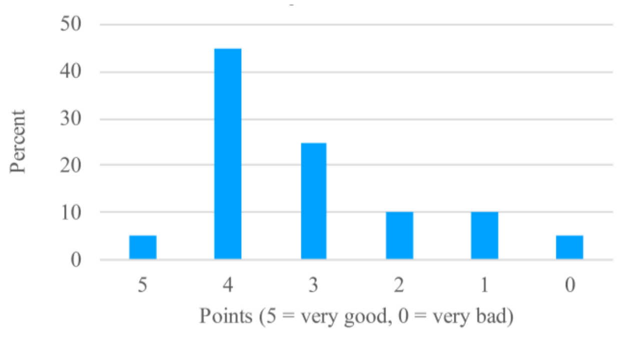

Fig. 4. Students' rating of the course in general

As far as the increase in knowledge is concerned the results after the second phase are almost the same as after the first phase and therefore show the perceived increase of knowledge throughout the project is about 20% (see Fig. 5). These findings were supported by an external evaluation of the course (see Fig. 6) by Bergstrøm Consult.

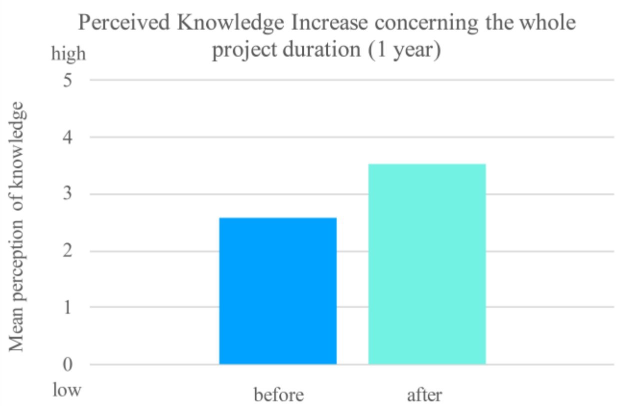

Fig. 5. Perceived knowledge before and after the complete project

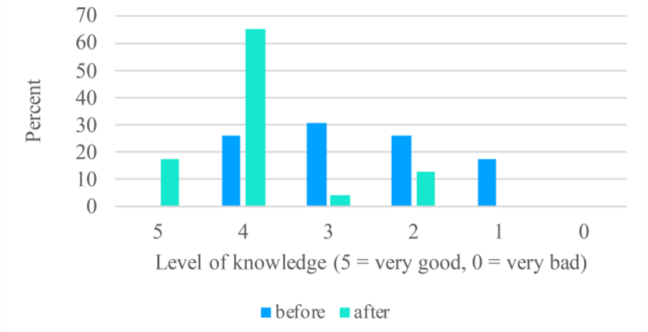

Fig. 6. Level of the students' knowledge before and after the project

In retrospect, we conclude that given these results, four of six learning goals that were addressed in this project have been achieved as the social, academic, real world and fun character of the project was valued by all:

- Understand the social challenges of demographic changes and develop perspectives for related future professional rehabilitation products
- Identify creative and innovative solutions for a given problem
- Communicate with customers and analyse their needs
- Implement Human Centered Design into projects

Two learning goals were partly achieved as teams were efficient when physically together and at those times team collaboration across disciplines worked well.

- Get experience on efficient work and communication in multinational and multidisciplinary teams
- Bridge the gap over discipline boundaries between students from health care, engineering, game design and computer science

B. *Other Stakeholders Perspective*

COMPANY PERSPECTIVE:

In spite of the reduction in the number of team members during the final semester, the companies reported valuable contributions from the students. Positive contributions reported were the students' ability to produce creative solutions and their commitment to the projects. In addition, the companies mentioned access to and contact/cooperation with the universities as important and valuable for them.

TEACHER PERSPECTIVE:

It was difficult for HEIs to get a committed company that wanted to participate and not all HEIs succeeded in contracting a company. Furthermore, it took some effort to synchronize the different organizational schedules and ECTS programs at the different HEIs. Some students got credit points at their home university while others did not.

The hours required for creating the MOOC were much greater than expected, as creating online learning material for such an interdisciplinary student group was very challenging. Nevertheless, it was educative to create the MOOC modules as well as to be able to work together on topics related to health promotion, electronics and gamification. All involved HEIs put a lot of effort in making this project succeed. Meetings were effective and efficient.

V. CONCLUSIONS AND OUTLOOK

Overall the collaborative learning approach adopted here proved to be successful in producing graduates who can effectively participate in multi-disciplinary projects. Close collaboration with the client companies proved to be especially beneficial to the students' learning in terms of timely clarification of requirements and validation of solutions. This reflects real life project development, something that the students strongly appreciated.

Our collaborative learning approach has proven to be a success as the students indicated that the MOOC increased their perception of the problem and issues involved, and the assignments given by companies were perceived as relevant. Furthermore, all HEIs involved were dedicated and committed to producing content and actively assisting students during the Erasmus project. There has been a vast amount of knowledge exchange between professors of the HEIs regarding course development, teaching approaches and evaluation methods.

As identified in the literature, student evaluations demonstrate the theory of collaborative working. Students regulated their own learning processes and worked together successfully, especially when co-located, indicating that knowledge construction is indeed a collaborative process. Moreover, as students were dealing with realistic contexts and relevant tasks, our approach supports cognitive constructivist theories.

We note that we underestimated the amount of work involved in developing a MOOC to support this course. In particular, it is necessary to keep the amount of ongoing maintenance as well as the evaluation and assessment of student work in mind. Synchronizing the curricula and assigning the same amount of ECTS for all students at the different universities is a key factor for maintaining long-term motivation and improving teamwork and communication amongst the students. Nevertheless, students that finished their graduation projects received compliments from client companies and the graduation projects were largely deemed of high quality by the HEIs.

ACKNOWLEDGMENT

This project was funded through the EU Erasmus+ strategic partnership programme. Project ID: 2016-1-N001-KA203-022052

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